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MARCH, 1925

SHORTHORN COLOR INHERITANCE
A. D. B. SMITH

DOMESTICATION IN PERU
O. F. COOK

GONGORA GALEATA—A REMARKABLE ORCHID
CHARLES TORREY SIMPSON

SELECTION OF BLUE-GRAIN CORN
G. N. STROMAN

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CONTENTS

SHORTHORN COLORS ..... A. D. B. SMITH 73

JUDGMENT DAY IN SHEEP WORLD 85

HEREDITY IN THE SNAPDRAGON (A Review) 86

THE STUDY OF PERSONALITY (A Review) 86

THIRTY-FIVE YEARS OF CLOSE BREEDING ..... G. N. STROMAN 87

PREDISPOSITION TO MENTAL DISEASE (A Review) 88

NOTES ON GONGORA GALEATA ..... CHARLES TORREY SIMPSON 89

THE BREAST-FEEDING OF INFANTS (A Review) 93

PERU AS A CENTER OF DOMESTICATION ..... O. F. COOK 95

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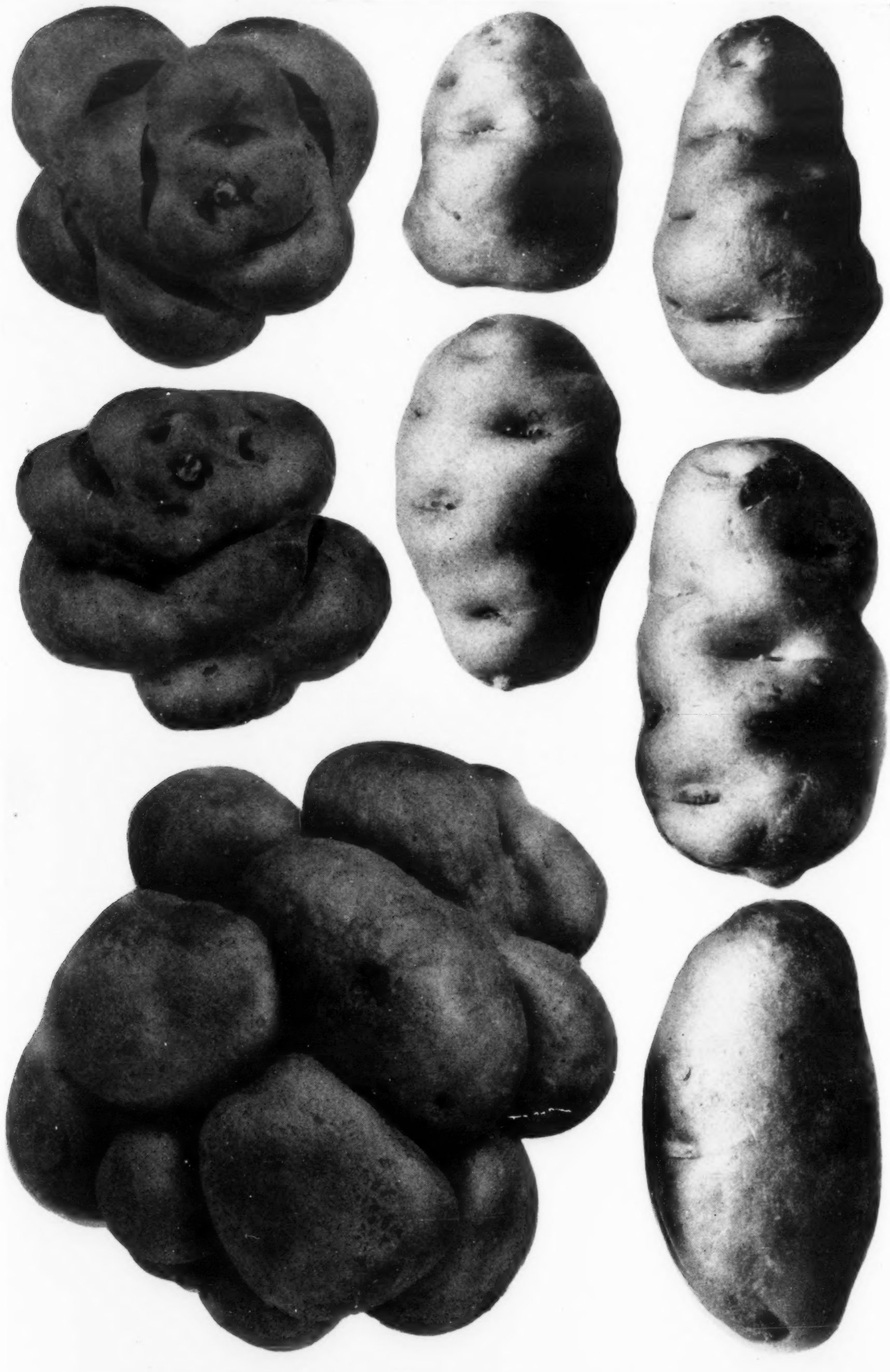

PECULIAR POTATOES FROM PERU

Frontispiece

We are indebted to the ancient Peruvians for the potato, and probably also for maize, tomatoes, sweet potatoes, and peanuts, to name only a few of the plants that appear to have been carried from Peru to other countries. At least seventy species of plants and four of animals were domesticated by these people; which, taken with other evidence, indicates that the Peruvian civilization was one of the oldest, if not actually the oldest, of which we have record. (See "Peru As a Center of Domestication," page 95.)

SHORTHORN COLORS

A Study of the Inheritance of Certain Color Characters in the Shorthorn Breed of Cattle

A. D. B. SMITH
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"IN THE study of the roan coat of this breed about the only thing which the results of Wilson, Laughlin, Wentworth, Barrington and Pearson, and Walther have in common, are exceptions which each found to the interpretations offered by the other writers." So says J. W. Gowen. It is indeed a case of *quot homines tot sententiae*. When the present writer embarked, under the direction of the Animal Husbandry and Genetics Departments at Iowa State College, on a study of this problem of inheritance of coat color in the Shorthorn it was with an open mind prejudiced in favor of no particular theory.

In any work of this nature the value of herd-book data must not be overstressed. Anyone who has gone amongst Shorthorn breeders will know that there are some who care very little for pedigree, and exert no care in registering calves. Others, interested in pedigree to a certain extent, care little about color; others again, interested in color, care little about what is to them the laborious work of exact registration. Not all the produce, especially the white calves, are recorded. There is also considerable difference of opinion regarding the exact terminology to be used concerning each type. In view of the absolute certainty of the occurrence of such errors, it is hardly likely that an explanation of the inheritance of coat color in cattle will be found to fit exactly to the data of the herd-books. Martini,[13] tracing the pedigrees of 1,285 calves, discovered twelve misregistrations, and these were from two of the best and most carefully managed herds in the United States. He was not able to get information from other herds whose owners were unwilling to co-operate with him. To take an example from a stud book, Anderson[1] has shown that chestnut is recessive to all other coat colors in horses. No case has yet been scientifically reported where two chestnuts ever bred anything else than a chestnut. Yet an examination by Hurst of the Thoroughbred stud book revealed nine blacks from 1,104 such matings, while Wilson, dealing with 51 Shire matings of a similar nature, obtained one black, one brown, and five bay, representing an error of about 14 per cent.

Theories of the Roan

The Monohybrid Theory. Many theories have been put forward to explain the mode of inheritance of the roan color of Shorthorns. Of these, the one that most closely fits the facts is the so called "monohybrid" theory advanced by Barrington and Pearson in 1906,[2] maintained by Wilson,[21] Walther,[18] and Sewall Wright.[22] This theory is analogous to that which accounts for the classical Blue Andalusian Hen. The pure colors, red and white, are homozygous, the roan being their heterozygote.

This was soon seen to fit the facts to a comparatively good degree but exceptions were noticed where red by red gave white or roan, white by white gave red or roan, red by roan gave white, white by roan gave red, and red by white gave red or white. These exceptions were frequently found to be due to faulty herd-book registration, but some were found to be authentic

and led Barrington and Pearson to conclude that this idea was inconsistent with any theory of the pure gamete. Wilson supported this theory with tables extracted by Mr. Bruce from the matings at Sittyton during the lifetime of Mr. Cruickshank. From these and other figures which have been collected by Wentworth[19] and Duck.[4] Table I has been compiled, showing, amongst populations taken at random over a very considerable period of time, a significant deviation from the monohybrid basis of only 5.8 per cent. The greater part of this deviation could easily be accounted for by misregistration in the herd-book. Half a per cent should more than cover authentic deviations which might be then accounted for by mutation. Duck[4] with 186 matings of white by white was able to establish no red offspring for a certainty. Neither by examining 2,567 matings of red by red was he able to establish any case of white offspring.

While no other theory so closely fits the facts as does the monohybrid, there are, nevertheless, two serious objections in addition to the one for which mutation has been advanced as an explanation. The first of these is that this theory cannot explain the possibility of roan breeding true. While it has never been shown that Shorthorn roan does breed true there is a presumption that this may be the case, for in England the Blue Albion breed of cattle, which is predominantly Shorthorn in its "make-up" and which apparently differs in coat color from the roan Shorthorn solely by the substitution of black hairs for red, is *reputed* to have been bred true for a considerable number of years. These Blue breeds also occur in Flanders and in France. Wallace[17] reports a blue breed of cattle in Bundelkhand, India. In all these cases, the blue roan, while varying in degree, apparently breeds true to the roan characteristic. Should this be so it is quite incompatible with the monohybrid theory.

The other objection is raised by a study of the herd-books, revealing that certain white bulls mated to red cows give a surprisingly large proportion of red calves. This has been shown by Lloyd-Jones and Evvard[12] in the case of Whitehall Sultan, 163573, and by Martini[13] in the case of his son, Maxwallton Sultan, 305870. The latter bull, in 56 matings with red cows, gave 13 red, 41 roan, and 2 white calves. While the two white calves can be dismissed as due to faulty registration or to mutation, the 13 red appear to make too large a proportion, especially when it is remembered that the bull was used and his calves registered by thoroughly trustworthy and well-known breeders, Rosenberger and Edwards, of Tiffin, Ohio. Martini searched for misregistrations in the progeny of this bull but could find

TABLE I—Significant Deviations from the Monohybrid Theory

Mating	% Red	% Roan	% White	Deviation	Total Matings
Red × Red	92.4	5.9	1.7	7.6	5424
Red × Roan	56.8	42.3	.9	.9	7759
Red × White	11.2	83.6	5.2	16.4	3132
Roan × Roan	30.1	49.3	20.6	.....	5921
Roan × White	4.9	56.4	38.7	4.9	688
White × White	1.8	3.2	95.0	5.0	345

Significant Deviation=5.8%.
Total Matings=23,289.

Compiled from the totals of the matings of Cruickshank (as recorded by Bruce)[3], Barrington and Pearson[2], Wentworth[19] and Duck[4].

TABLE II—Comparison of the One Factor and the Two Factor Hypotheses
(From Tables Compiled by Sewall Wright)

Parents Red x White	% Red	% Roan	% White
By dihybrid hypothesis	55.9	21.3	22.8
By monohybrid hypothesis	0.0	100.0	0.0
Actually found	2.2	95.9	1.9

Parents Roan by Roan	% Red	% Roan	% White
By dihybrid hypothesis	16.7	78.9	5.2
By monohybrid hypothesis	25.0	50.0	25.0
Actually found	26.6	52.9	19.5

none, although he did in other cases. Further data collected by the present writer would show that two more of Whitehall Sultan's white sons, Fairacre's Sultan, 354154, and Snowbird's Sultan, 354160, twins, have thrown a considerable proportion of red calves when mated to red cows.

These two objections, which, if correct, will nullify the monohybrid theory, are further dealt with in this paper.

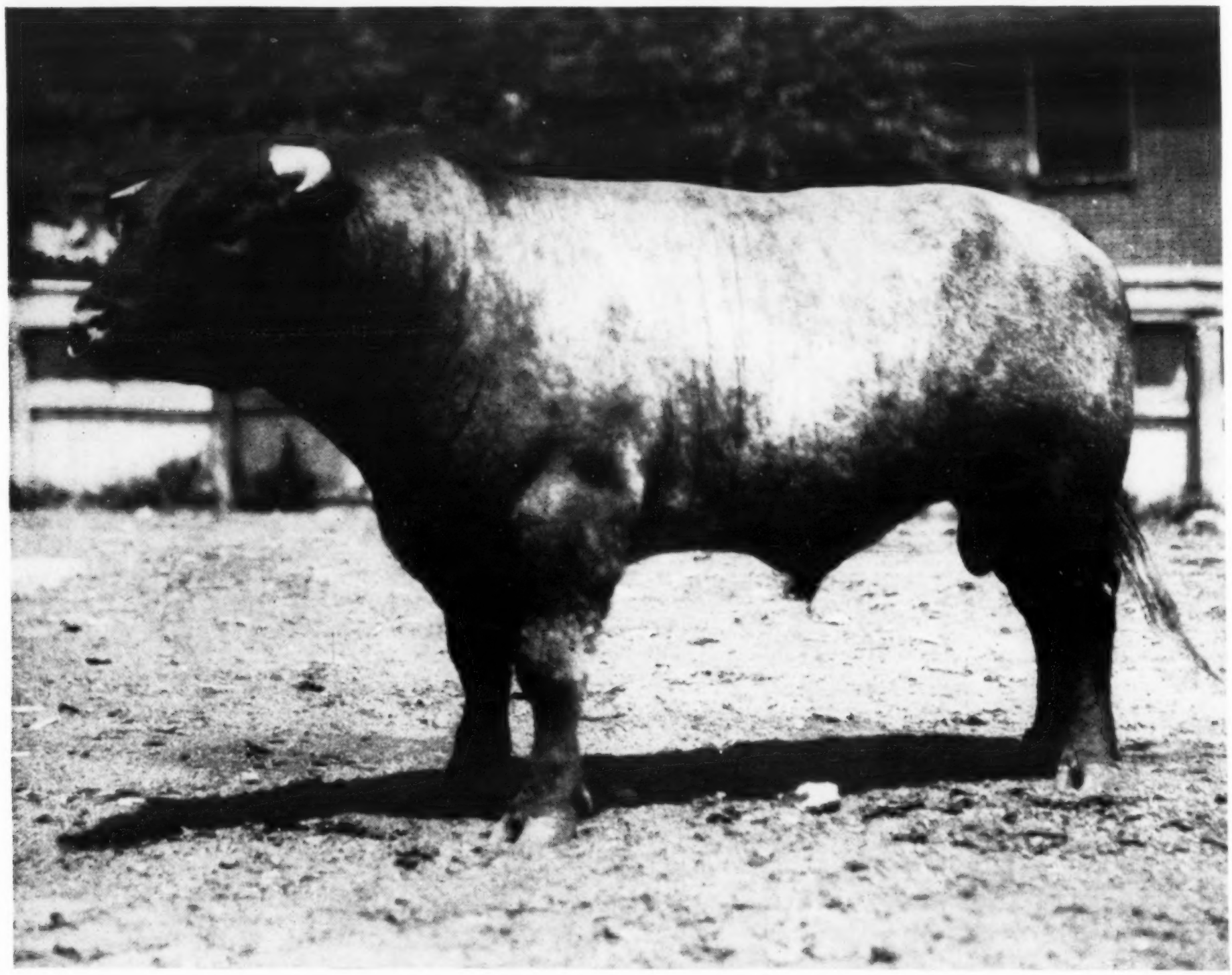
Laughlin's Theory. H. H. Laughlin in 1911 advanced an ingenious but exceedingly complex theory on the basis of the existence of two groups of genetically independent sets of hairs which intermingle. The one set has its white dominant to red, and the other red dominant to white. The dominant white is a "positive white," the recessive an "albinic white." The area governed by the first set is about the two flank belts, underline, median line of face, and a fine network over the body. Set Two covers the neck, sides, back, hindquarters, legs, and anything else not covered by Set One. (In this connection it might be remarked that Gowen[8] has shown that white spots on the face, neck, shoulders, rump, flanks, and legs appear to be recessive.) It would be tedious to discuss in detail this theory which, while it can account for every possible combination giving every possible color (except red by red giving white) is too cumbersome and is not borne out by any similar situation in animal genetics. It has moreover one or two additional discrepancies in that certain genotypes which it postulates have, so far as is known, never been encountered. Laughlin in a subsequent paper (1914) has to resort to complete linkage of factors to account for the fact that a white Shorthorn with a red belly is never seen. As Wright[22] says, "Unfortunately, the general facts become inexplicable on this theory."

The Dihybrid Theory. This hypothesis, advanced by Wentworth in 1913, postulates separate factors for roan and white. The roan factor P is dominant to the non-roan p and acts as an epistatic on the factor for red, R, which is dominant over the absence of color, white, r. This gives a 9:3:4 ratio in the F_1 when two such roans as these are mated:

P^1	RrPp × RrPp	Roan × Roan	
	gives		
F.	1 RRPP 2 RRPp 2 RrPP 4 RrPp	9 Roan	
	1 RRpp 2 Rrpp	3 Red	
	1 rrPP 2 rrPp 1 rrpp	4 White	

This theory accounts for all possible combinations giving all possible colors except red by red giving a roan or white by white giving a red or a roan. For these exceptions Wentworth falls back on misregistration in the herdbooks. In his tables he shows 1.2 per cent whites from red by red matings and 2.6 per cent reds from white by white matings. Thus, while his theory has been evolved largely to account for the former case, it fails to do so in the latter, which shows double the deviation. In the writer's opinion, considering the many accidents of registration which occur, both percentages are insignificant. There are several objections to this theory. In the first place it implies the production of white animals in which the roaning factor is absent. If there is such a white Shorthorn a very prolonged search will be required to unearth it. Having studied the matings of many white individuals the writer has never come across a white which, when mated to reds, gave solely red or white.

This theory is most definitely disposed of by Sewall Wright[22] who shows that the proportions required from a population built up of such genotypes and mating more or less at random, is not in the very least borne out by the facts. He says: "Thus



AN "EVEN ROAN"

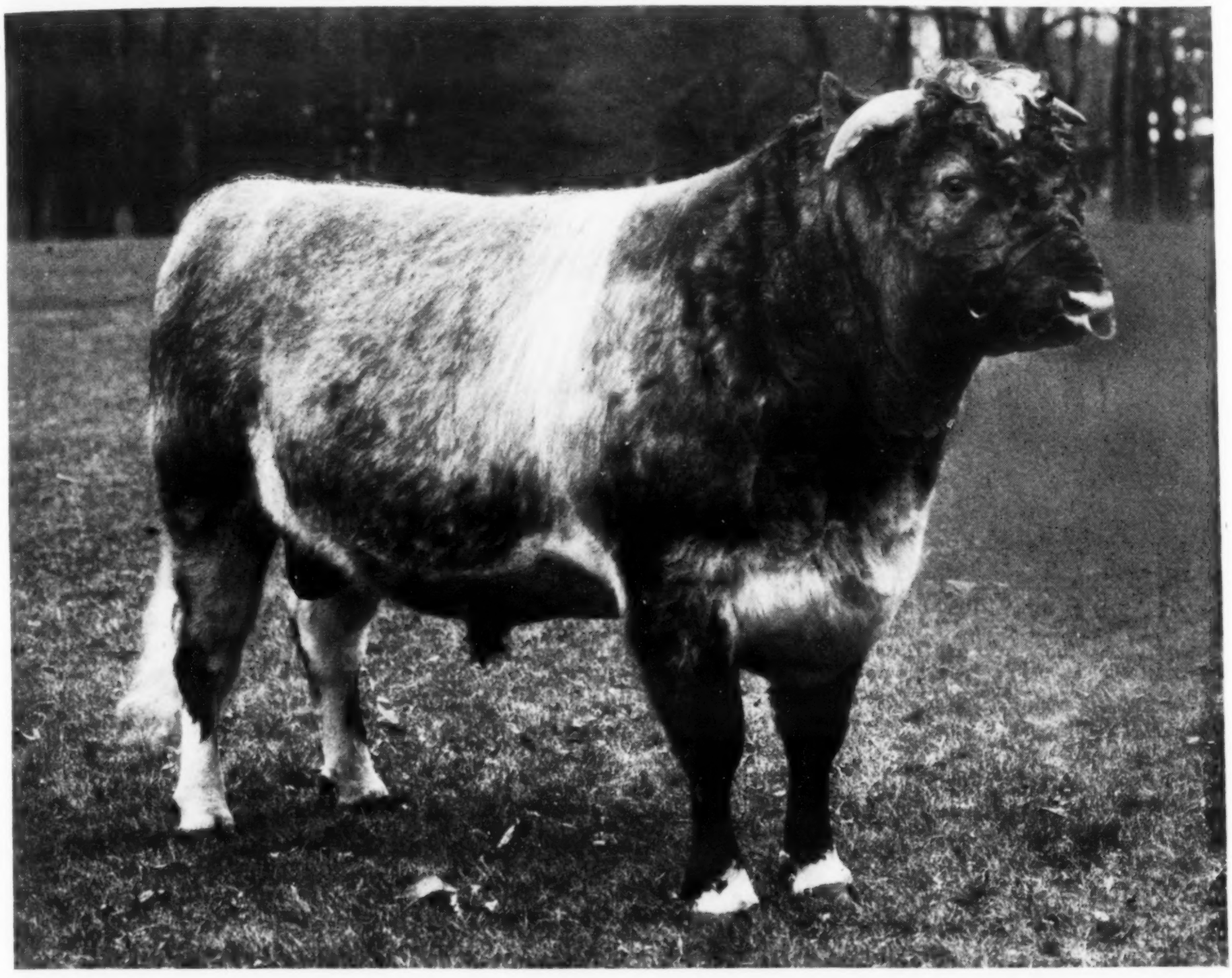
Figure 1

Shorthorn Bull, "Gainford Enchanter" 1137642. Note that he carries no white spotting. His underline is roan like the remainder of his body. The intensity of the roan varies gradually, the deepest shade being at the extremities. This bull has no star.

with 47.9 per cent. of the animals red, .479×.479 of the matings should be red by red, giving an expected number of calves of 1,998, whereas the actual number was 1,851. The table indicates a distinct excess of matings of roan by roan and white by white. Roan by white and roan by red seems to be the most discriminated against." Dr. Wright supports these figures with many others and several tables which effectively dispose of this theory, unless, indeed, close linkage accounts for the numerical discrepancies. But this is considered later.

Duck's Theory. Duck in 1923 put forward a theory elaborating Wentworth's dihybrid and at the same time retaining the heterozygous part of the monohybrid. Here again there is a factor for color *R* and its absence *r*. The solid red is the homozygote *RR*, white is *rr*, while red-and-white is the heterozygote *Rr*. Roaning is caused by a dominant extension factor *E* which can only act on the heterozygote *Rr*. According to its author this gives:

RRee RREe RREE	Red
RrEE RrEe	Roan
rrEE rrEe rree	White
Rree	Red-and-white



A "SPOTTED ROAN"

Figure 2

Shorthorn Bull, "Coronet's Crown," 723345. Notice the patchiness of the roan, the distinctly white underline, white belt behind the shoulder and large white star. This spotted condition appears to be recessive to solid color and is probably due to the same genes as the spotting in the Holsteins.

In some cases it may be possible that a red-and-white animal whose marks show a certain roaning may be of the roan genotype *RrEe*. This theory supposes the effect of the factor *E* to be intensified when it is a duplex. Duck says that this hypothesis explains many of the apparent contradictions which occur in color matings, but without discussing them. Since this theory does not attempt nor desire to explain the production of reds from white by white matings or whites from red by red, the writer having already established that both these colors breed true (see note on monohybrid theory), and as it does not try to show that roans can breed true, the only advantage it can have over the monohybrid is that it explains the fact that certain whites, when mated to red produce a significant number of reds. This it does at the expense of the general facts of the case, for, like the dihybrid theory, it postulates a white which carries no roan, and, introducing a new complication, demands a red which does. In this latter case Duck states:

"That the red of the Shorthorn can also carry the roan extension factor is unquestionably proven by the results obtained from the various matings in Table III.' This table of Duck is an excellent one, giving the herd-book results in 11,685 matings. If a significant number of reds do carry roan,

and this theory demands that about three out of every four do so, then matings of red by red-and-white demand 50 per cent red, 25 per cent red-and-white, and 25 per cent roan, breeding at random. The figures obtained by Duck are 47 per cent red, 31 per cent red-and-white, and 20 per cent roan for 446 matings (9 whites were recorded also). Table III shows the results of this mating from other sources.

Thus, even by themselves, Duck's figures give rise to doubts which are verified when those of the other investigators are examined. The fact that reds, including red-and-whites, when mated together give only 5.9 per cent roans by no means goes to prove that reds carry a latent roan factor. It is, rather, pretty useful proof that they do not. The explanation as to why the red-and-whites mated to reds gave 20 per cent roan according to Duck's figures is not hard to seek when it is remembered that as a great many reds which have a little white are registered as red (particularly in America), it is chiefly those reds which have considerable white which are registered as red-and-white. It is possible that not a few red-and-white parents in the red by red-and-white matings could have been roan and have given rise to roan, while not a few of the roan offspring may have really been red-and-white.

Furthermore, reds mated to what Duck admits is their allelomorphic color, black, have never been known to give either roans or blue-greys. Duck explains this by saying that black is completely dominant in the heterozygote, ignoring the well established fact that a Galloway black with a Shorthorn roan gives rise to about 50 per cent black and 50 per cent blue-grey, and with a white Shorthorn, which is usually more "prepotent" for the roaning factor (i. e., homozygous, according to the monohybrid theory), gives 100 per cent blue-grey. Roans homozygous for the roaning factor, *RrEE*, do not appear to exist, yet this hypothesis demands their appearance. Thus while some of Duck's figures appear to fit the facts rather better than the monohybrid, others are no improvement upon it. Those that do, can, in every case, be easily explained by the doubtful division line which exists between roan and red-and-white.

An equally serious objection is that in other breeds the colored-and-white breed true . Nowhere else in the cattle world does spotting appear to be heterozygous. It has been clearly shown that it is a recessive condition by Kuiper,[10] Plank,[16] and Durham.[5] Moreover Duck in his paper, makes some rather sweeping, if not illogical, statements such as that the black of the Galloway "acts differently than the red of the Shorthorn towards assuming a pied pattern in the phenotype," due to the presence of some inhibiting factor which acts only in the presence of the black, though in the next sentence he is careful to point out that black and red are allelomorphic. While this is vaguely possible it is improbable, especially where the roan factor is taken rather as altering the type of the spotting than as scattering red or white hairs throughout a pigmented coat. Another statement to the effect that roan by white will give more roans than will roan by red must, although supported by the figures in the table, be treated with reserve in view of the fact that there is a distinct prejudice amongst

TABLE III—Progeny of Matings, Red by Red-and-White

	Obtained				Percentage			
	Red	R.& W.	Roan	White	Red	R. & W.	Roan	White
Duck[4]	210	138	89	9	47	31	20	2
Wentworth[19]	223	119	23	22	57	31	6	6
Bruce[3]	31	11	6	0	65	23	12	0
Barrington and Pearson[2]	82	77	11	0	48	45	11	0

many breeders against registering white calves unless they show promise of becoming good individuals.

Thus this theory breaks down in a good many more points than the simpler monohybrid. Although certain aspects are plausible, taken as a whole, and especially in relation to facts demonstrated in cattle outside the Shorthorn breed, the theory is reared on premises that are none too sound.

The Inheritance of Spotting

In view of the fact that there has been much debate concerning spotting and also that there are amongst the roan Shorthorns many of uneven roaning which show distinct white patches coming through the roan, it was thought that this spottedness was inherited more or less independently of the roan factor or factors. It was further thought that the spots occurring in the red-and-white could equally well occur in the roan. A study of the Shorthorns at Iowa State College, though it is by no means complete, seems to show that this is so. The various patches on the animals that were studied seem to show that they were recessive (this is not conclusive) with a distinct tendency towards the domination of the smaller patches over the larger. To take one example, that of the vertical belt, which frequently occurs just behind the shoulders, regarding the inheritance of which data are given in Table IV.

When a correlation of the spottedness was made, it was found that the inheritance of the individual spots does not appear to be independent of the inheritance of the other spots. The vertical belt which is present on the flanks, appears usually only after the rest of the body has been spotted. There is then a gradual recession of color, not so much of a spot at a time as in the size of the spot. The places which tended to develop white are roughly in this order: Underline (small), brisket (small), shoulder patch (slight), star (small) topline (rear end, small patch), tail, underline (increase), star, flank patch (slight), topline (increase), tail (increase), underline (extending up the sides), an all white brisket, white shoulder, white continuous topline, large star, distinct flank bands. In the end, these all merge into each other, leaving only red patches. A study of the Holstein- Freisian breed reveals that the patches there are inherited in much the same manner and places.

When an analysis of the pied and solid Shorthorns was made (irrespective of roaning), the results summarized in Table V were obtained

The work of Kiesel cited by Lang[11] and Kuiper[10] gave:

P₁ Limburger *Self* × Dutch *Pied*

F₁ *Intermediate Spotting*

Backcross to Self:	Backcross to Spotted:
22 Self	*84 Spotted*
29 Spotted	*6 Solid**

The intermediate spotting was in many cases only a small white underline. This would show the tendency of the self to dominance. The fact that

TABLE IV—Inheritance of Spotting Behind the Shoulder in the Shorthorn

No.	Mating	Produce
1	No Belt × No Belt	=1 No Belt
6	Slight Belt × No Belt	=5 No Belt & 1 Slight Belt
4	Slight Belt × Slight Belt	=2 Slight Belt & 2 Large Belt
5	Large Belt × Slight Belt	=5 Slight Belt

*Kuiper says that these 6 were really spotted.

TABLE V—Inheritance of the Pied and Self Conditions in the Shorthorn

No.	Mating	Produce
1	Self × Self	=1 Self.
3	A Pied × Self	= 2 Self, 1 A Pied,
3	B Pied × Self	= 1 Self, 1 B Pied, 1 D Pied
7	C Pied × Self	= 5 Self, 1 B Pied, 1 C Pied
2	D Pied × Self	= 1 Self, 1 D Pied,

A, B, C, and D Pied are relative. "A" Pied shows little spotting and "D" Pied considerable.

the spotting of the F_1 is intermediate is probably due to the large number of heterozygotes amongst the solids and also to solids with white underlines.

Plank[16] served six descendants of a Jersey Cow alternately by a black bull and a spotted one. The calves were all self colored with the exception of a little white on the underline. This supports the idea of the dominance of the self condition.

Funkquist and Boman[7] in Sweden found that marked calves came from matings of unmarked parents, and unmarked calves from parents both marked. This is adverse to the idea, but the evidence presented is not conclusive.

Hooper[9] crossed a Holstein Bull with two Jersey cows and got two black, two black-and-white and one black with white legs. The reciprocal cross gave only black. The figures here are small.

Richardsen (1914), quoted by Durham[5], said: "In crosses between single colored and red-brown Netherlands, a very few self-colored animals were produced." The meaning here is doubtful and the description vague.

Wallace[17] (p. 158) mentions that a Red Polled bull, Excellency, used on 25 West Highland cows, and 7 Shorthorn and 1 polled Angus produced calves in 1900,-01,-02 all of which were solid red save that one calf from a West Highland cow had two white feet. He also quotes Lee from Ohio who said that a Red Polled bull on 16 Shorthorns and grades gave calves all of a uniform red.

Gowen[8] made a detailed analysis of crosses amongst the Aberdeen Angus, Jersey, Ayrshire, Guernsey and Holstein breeds. In his summary he concludes that it is only in the "inguinal region" that any dominance of white spotting occurs. The white spot on the face, he says, as well as on the shoulders, rump, flanks and legs are, in general suppressed in the offspring, where animals with these markings are mated to solid colored animals. Because he finds the "inguinal spot" showing dominance he concludes that spots are inherited separately. From this data of Gowen the present writer finds there is a distinct tendency for the spots to go together. Gowen places a solid colored animal which has a small white spot on the teats in the spotted class. Thus "Kayan," an Aberdeen Angus bull, whose blood is in a large number of the matings, is treated as being of the same phenotype as the Holsteins. The present writer believes that this "inguinal spot" may be inherited separately from the pied condition and is similar to the dominant white head or white belt that appear in other breeds. Working on such an hypothesis, Gowen's results would read:

Self × Pied = 19 Self : 6 Pied.
Pied × Pied = 2 Pied.
Self × Self = 20 Self.

All the breeds were involved in these matings, the Aberdeen Angus predominating. The matings of the Aberdeen Angus bull (solid colored save for the inguinal spot and homozygous for the solid condition) with Pied cows gave 12 solid, as expected, four of whom had the "inguinal spot." Altogether, out of 31 matings of other breeds with the Aberdeen Angus, 30 solid colored colves were produced. The one exception was really solid but for a small white star. Thus Gowen's work may be adduced as proof that the self condition is dominant to the pied, and also that light Pied is recessive to dark Pied.

Lloyd-Jones and Evvard[12], mating solid black Galloway cows to a white Shorthorn bull got 53 blue-gray calves all having an even roaning. The only spots in the F_1 were those occurring around the teats. The F_2 showed distinct patchiness in some of the blue-greys, roans, blacks and reds.

Finally, Dunn, Webb and Schneider[6], in a study based on the official diagrammatic records of the Holstein breed, found that the differences in the amounts of spotting are inherited and amenable to selection, that segregation of factors determining the grosser dif-

ferences in spotting occur, that there is probably some degree of blending, that the darker grades are probably dominant over the lighter grades, and that the male appears more "prepotent" in transmitting darkness.

It would therefore seem logical to assume that there is acting in the Shorthorn breed the same factor which in its recessive form causes the pied condition in other breeds. This factor probably seldom reaches quite the same degree of lack of pigmented areas as sometimes occurs in the Holsteins because it is severely discriminated against, spotted reds and roans being looked upon with disfavor by the Shorthorn breeders. That this factor is recessive has been clearly shown by the results of others. Further proof that this is the case may be found in the fact that, although for many years the solid red and very even roan have been by a long way the favorite colors, they are by no means always the most common at the present day. Had the pied been dominant, the breeders could have eliminated the spotted beasts with comparative celerity.

It is also worth remembering that the Shorthorn has got Dutch blood in its genetic "make-up" and that therefore it is in no way remarkable that it should possess certain color markings which are common to the breeds of Holland. Indeed it would be remarkable if it did not possess them.

Conclusions

This theory of the inheritance of spotting could be taken in conjunction with any other theories regarding the inheritance of the roan condition. Besides those presented in the first part of this paper there are two other explanations that might be used to fit the facts. One is a dihybrid theory similar to Wentworth's idea but involving close linkage between the roaning factor and the color factors, reducing it almost to a monohybrid. (But hitherto no linkages have been found and it is doubtful if there exists such a close one as the figures in this case demand.) The other is a series of multiple alleiomorphs such as Nabours has shown to exist in Paratettex. (To be proven this would need almost prohibitive investigation.)

A review of these theories prompts a return to the monohybrid and an examination of the objections to it. It may be recalled that there were two. The first was that while no roans have been reported as breeding true, blue-grays which genetically are not dissimilar in this respect are reported to do so. Investigation shows that this is hardly the case in the Blue Albion breed in England despite the fact that breeders sometimes produce figures to show that it does. The present writer has come across a belief held by several Blue Albion breeders including one of the best known, Mr. Trafford of Ashbourne, that the original British Freisians were "sports" from the blue and white cattle which have been bred in Derbyshire for over 200 years. This is interesting in connection with spotting inheritance. As a result of correspondance with the Political Agent in the Bundelkhand, India, it has been ascertained that white and black cattle exist alongside the blue mentioned by Wallace[17] (p. 224.) and that the blue throw solid colors.

The other objection to the monohybrid theory was the large number of reds thrown from certain matings of white bulls and red cows. The writer has been able to examine this further and he finds that these reds should be registered as roans, for there is a tendency amongst white bulls to throw roan calves which appear almost red. One instance may typify several that he has come across. Collynie Royal Leader, bred by Mr. Duthie Webster of Collynie, Scotland, is red in appearance with a small white star and a small spot on the underline. He is registered as a roan and Mr. Webster has no hesitation in calling him that, for at birth his roaning was fairly distinct though it is barely visible just now. This bull calf is by a white bull, the famous Balcairn White Eagle (153591) and is out of a red cow.

In his 1924 crop of calves Balcairn White Eagle sired nine, four of which were in appearance red though really roan, three being bulls and one a heifer. These four "almost reds" or "red roans" as Mr. Webster describes them in the herd book, all came from red cows. Two distinct roans were also thrown from red cows by the same bull.

A corollary of this also holds true, a red bull on a roan cow giving a white calf. The writer has seen the produce from such a mating on the farm of Mr. Gordon Auld, near Guelph, Ontario. The sire was Browndale Monarch, an apparent red. Further investigation, particularly form a breeder who had known him as a calf, revealed the fact that in his youth this "red" bull was a roan and for breeding purposes should still be classified as such. He apparently takes after his sire, Browndale, in this respect.

It is by no means impossible for the borderline of the phenotypes to be difficult to distinguish. It takes place in animals. Sewall Wright[22] has shown that the tortoiseshell guinea-pig can be selected either for solid red or black, only a very minute examination revealing that it is not a self colored animal. The work of Whiting[20] illustrates the same thing in the tortoiseshell cat with selection for black and yellow. The Sapphire Hog, a blue-gray breed of pigs in New England described by McLean[14] arose from a white sow which showed the faintest tinge of blue roaning. The experience of the present writer inclines him to believe that Walther[18] was right when he added to Wilson's[21] three sources of error, a fourth which was this difficulty of distinguishing red and white from roan. He also pointed out that some animals which show pronounced roaning at birth loose every trace of this in latter years, and that the heterozygous form transgresses either parent.

Thus considerable doubt is cast on the validity of the two objections to the monohybrid theory. Since it is the simplest and adequately explains the general trend of facts it would appear wise to adopt it as a working hypothesis. This, coupled with the hypothesis that spotting is a recessive condition (excluding in cattle generally, the dominant markings of the head, belt and, perhaps, "inguinal spot") would give a fairly simple explanation that could be readily understood by the average breeder.

If, then, it be assumed that:

R=Red color (incomplete dominance) and its allelomorph r=White, the heterozygote Rr being Roan.

S=Self color (dominant) and its allelomorph s =Pied, then the various types of the Shorthorn coat color may be represented as in Table VI:

There will be, of course, the interaction of many subsidiary genes modifying each type to a considerable extent. Thus the action of the "inguinal

TABLE VI—Shorthorn Coat Color, Phenotypes and Genotypes

Type	Description	Phenotype	Genotype
Red	Self or Solid color with perhaps an "inguinal spot"	RRS	RRSS or RRSs
Red & White	Distinct white underline at least	RRs	RRss
Roan (even)	An even mosaic of any intensity	RrS	RrSS or RrSs
Roan (uneven)	Of any intensity but spotted	Rrs	Rrss
White	With dark eyes and some pigmented hairs in the ears	rr	rrSS or rrSs or rrss

A "RED ROAN"

Figure 3

Apparently a red but genetically a roan and correctly registered as a "red roan." "Collynie Royal Leader," sired by the white bull, "Balcairn White Eagle" (153591), and out of the red cow "Eliza Lass" (Vol. 63, p. 1226). At birth this calf bore distinct traces of roaning which are now barely visible. This seems to be due to modifying factors.

spot" dominant factor may cause a considerable number of reds of the phenotype *RRS* to appear as red-and-white, *RRs*. The action of factors on the roan may so darken the coat color and modify it as to cause the phenotype *RrS* to appear as a red *RRS*, or, even more likely to cause *Rrs* to appear as a red-and-white *RRs*. The same, or similar factors acting in the opposite direction might make the light roan of phenotypes *RrS* and *Rrs* appear as white *rrS* or *rrs*. Some white bulls mated to spotted cows would give only spotted offspring.

How to Breed the "Solid Red" and the "Even Roan."

In order, therefore, to obtain the "nice even roan" it would be necessary to mate solid red and even roan with each other. If a white animal were used it would be necessary to guard against the possible introduction of spottedness. Eventually a race could be bred true for the solid colors, though there would, for many generations, be a tendency for spotted animals to appear. It would on the other hand be much easier to breed a race of spotted animals by simply mating roans amongst themselves.

Summary

Previous hypotheses which explain the manner of inheritance of the roan color of the Shorthorn are reviewed in this paper and a note is made concerning the reliability of herd book data. The significant variation form the monohybrid theory is found to amount to 5.8 per cent amongst 23,289 matings. The two big objections to this theory, that roans breed true and

that certain white bulls mated to red cows throw red calves, are discussed in the latter part of the paper. Doubt is thrown on the possibility of roans breeding true. Concerning the second objection it is pointed out that the line of distinction between roan and red is not clearly demarcated and, in the writer's opinion, it is this that occasions these red calves.

The theory put forward by Duck in 1923 is discussed and several objections raised. It appears to be untenable.

A study of the inheritance of spotting in Shorthorns at Iowa State College and a critical examination of the crosses of Gowen as well as a survey of other work inclines the writer to the belief that the self condition is dominant to the pied and that the inheritance of spotting in the Shorthorn is the same as in other breeds of cattle, being independent of the basal color.

A table is elaborated combining the monohybrid theory with the recessive pied condition and suggestions are made as to how to breed in order to obtain the different colors.

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Judgment-Day in Sheep-World

June is not the season for shearing in New South Wales, but I was just in time for another occasion of even greater interest. This was the "classing" of the sheep by an old man of dazzling reputation who has his regular clients and goes about from station to station, passing individual judgment on each animal and receiving a neat $250 a day for his expert knowledge.

As I sat on a stool at his side in the great shed divided into runways like an imperfect maze, while one after another the sheep were rapidly passed along the line until they came to a full stop between his knees, I had a bizarre and vivid sense of the ways of Providence made manifest. Inexorable and inscrutable as God, the old man ran his hands over the body and peered into the crinkly yellowish mat of fleece which he separated with exploring fingers. A few seconds, and the animal was given a push that sent it trotting down this lane or that to the large pen where certain of its fellows moved about quietly and without purpose.

The finest were saved for special breeding, marked with chalk on the forehead to indicate the particular qualities which were to be handed on reinforced or modified by the character of the carefully chosen mate. These were like the few of genius among mankind, set apart in their superiority. In the next pen were the sheep of talent, above mediocrity, only missing the supreme class by some slight fault of wool-distribution or bony structure. Then came the mass of ordinary folk, the competent but undistinguished members of society—"a good flock ram"—"a good flock ewe"—I shall always hereafter think of those words of kindly dismissal with which the old sheep-classer sent the Mr. Babbitts of sheepdom pattering down the line.

Finally came the culls, the weaklings, marked on the shoulders by the "Devil's grip," imperceptible to my eyes, but sure to become more marked when the yearlings grew older, thin fleeced, perhaps reverting to original type, bare underneath. Culls fill our tenements, our prisons, our miserable holes of existence, perhaps because they have slipped back to an earlier type with characters that the generations have gradually modified, unable to cope with our stringent requirements, perhaps with a kink in their bones—men, too, are sometimes born with the "Devil's grip" on them.

And sometimes they are over-bred, over-civilized. Selection has put wool upon the under part of their bodies which were originally thinly covered; and the same process leads in some instances to an encroachment of wool over their faces, which must be avoided lest it blind their eyes. Second by second they passed under the old wool-classer's hands, while he murmured to me under his drooped yellowish mustaches: "Here's style in the wool—see the lustre and the crimp—a bit on the coarse side—a stud ram—a little more on the belly and he'd go into the first pen."

"Steady, dear." This in a kindly voice to a restless ewe. And as he grasps the wool in his hands, a sententious apothegm: "What fills the hand fills the bale; what fills the bale fills the pocket."

Occasionally there is a quick bleating protest, and one of the Babbitts makes a rush on its wooden sticks of legs for the stud pen. But there is no appeal. The culls swarm unconscious, unremonstrant in their large square pen, they who must be cast out of the flock. Second by second they pass under the old man's hands. He would perhaps be shocked if I told him that the large shed divided into runways, with its ceaseless tap of small feet, its occasional uncomprehending bleat, gave me a sharper sense of God than anything else has ever done in this world.

"A stud ram—a good flock ewe—we can not keep this one, there's a weakness of the withers—steady, dear."—NANCY BARR MAVITZ, in January, 1925, *Sunset*, "More Wool or More Men."

Heredity in the Snapdragon

UNTERSUCHUNGEN UEBER DAS WESEN, DIE ENTSTEHUNG UND DIE VERBERBUNG VON RASSENUNTERSCHIEDEN BEI ANTIRRHINUM MAJUS, by *Erwin Baur*. Bibliotheca Genetica, Vol. IV. Pp. 170, with 49 illus., 3 pedigree tables and 5 colored charts. Price $8.70. Leipzig, Verlag von Gebrueder Borntraeger, 1924.

In this volume Dr. Baur publishes the results of his breeding experiments with snapdragon, which have continued for twenty years, during the last decade of which from 25,000 to 50,000 plants have been grown each year. For details of the genetic analysis one must consult the original; the general character of the results seems to be in good agreement with those secured in Drosophila and other material. Some experiments in inbreeding produced rapid degeneration, which Dr. Baur thinks can not be explained by the hypotheses of homozygosis with which G. H. Shull, E. M. East and others have accounted for the results of their own experiments. The mass of richly illustrated detail in this book forms an important contribution to plant genetics.

P. P.

The Study of Personality

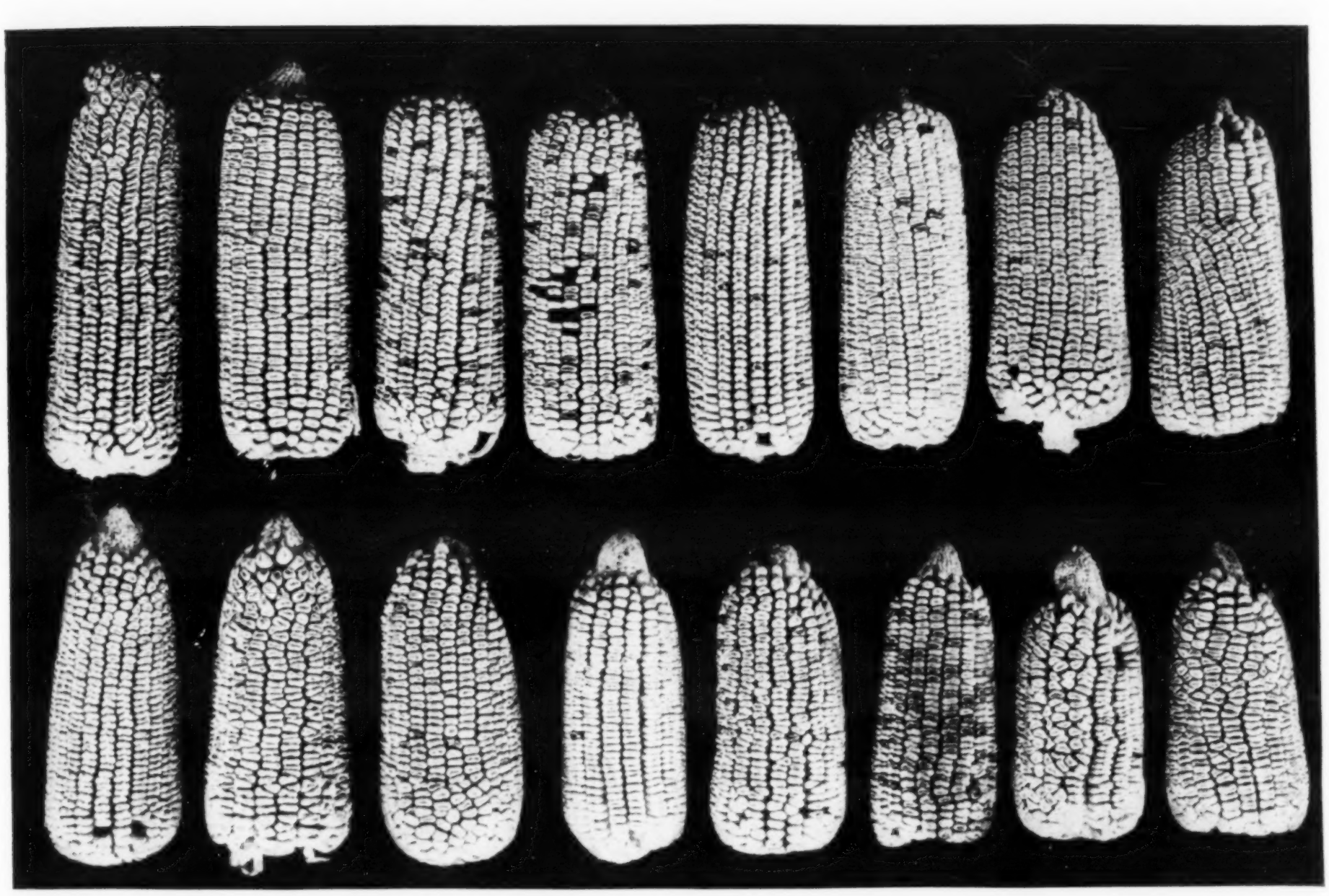
TEMPERAMENT UND CHARAKTER, by Privatdozent DR. G. EWALD, professor of psychiatry at the Univ. of Erlangen. Pp. 156. Price $2.25. Berlin, Verlag von Julius Springer, 1924.

Dr. Ewald attempts in this book to establish the concepts of temperament and character on a purely biological basis. He defines temperament as a factor related to the "Biotonus' of mental life, causing increase or decrease in the intensity and tempo as well as the tonus of the "Vitalgefuehle." Character, on the other hand, is estimated "on the ground of all the reactions which an individual experiences in the course of his life, in response to the most diverse stimuli operating on him." The author then proceeds along lines familiar in the modern European doctrine of human types, distinguishing a sanguine or hypomanic, a normal, and a melancholic or depressive temperament; differences in the operation of the glands of internal secretion are supposed largely to account for these differences in temperament. Character is divided into the "affective excitable" (men of feeling) and the "affective unexcitable" (men of thought). These are in turn subdivided and an attempt made to designate all human types by mathematical formulas based on these categories. Finally, the whole system is applied to problems of pschyiatry. I must confess that much of it sounds metaphysical to me. It would seem that the genetics of these so-called types should be investigated more fully before much dependence is placed on their use in diagnosis.

P. P.

THIRTY-FIVE YEARS OF CLOSE BREEDING

G. N. Stroman
Texas Agricultural Experiment Station



EARS OF THE OLD NATIVE BLUE GRAIN CORN

Figure 4

Sixteen random ears are shown of the strain which has been grown for thirty years in Brazos County, Texas.

RANDOM samples of a variety of blue-grain corn grown by a farmer in Brazos County, Texas, were of such remarkable uniformity as to attract the attention of the author. Information brought to light about the history of this corn appears to be of sufficient interest to be put on record.

About 1883, Mr. T. F. Bullock moved from Louisiana to Brazos County, Texas, and brought with him a mixed white and blue grain corn. One of his new neighbors, Mr. I. M. Cook, obtained some of this seed, and the variety proved so well adapted to that region that he grew it every year for thirty-five years and is growing it today.

This corn was called "Old Native" or "Native Blue Grain," the original source of which the writer was unable to discover. Mr. Cook has selected his seed continuously for thirty-five years so as to embody its original characteristics, and today his corn fairly well answers his description of the original "Native Blue Grain."

Twice during the thirty-five years he has grown it, the strain has been contaminated by foreign pollen. This occurred about ten or twelve years ago. One of the contaminating varieties was

a red cob (Blow corn) and the other was a yellow dent, both of which, Mr. Cook says, still show their effect in his corn even though he has continuously selected for the opposite type (as to cob color and endosperm color).

The original type, according to Mr. Cook, had loose, soft, deep, white, shoe-peg kernels, some of which were blue; a white cob and small stocky plant, and husks which came well down over the ear.

Mr. Cook's strain today is not very different from the description of the original type. The striking exceptions are the shorter ear and a shorter grain. Figure 4 shows sixteen random ears grown by Mr. Cook.

Breeding Tendency

During the last thirty-five years Mr. Cook has selected for the old original type, and he deplores the fact that he can not hold absolutely to it, as the strain tends to breed to a longer ear with a short, flinty grain. He admits that he approaches it, but is disappointed in that he does not approach it to perfection.

The longer, flinty ear toward which this variety tends is found in other strains of blue grain corn grown in Eastern Texas. This may be the result of less rigorous selection.

It is the opinion of the writer that Mr. Cook's "Old Native Blue Grain" is a naturally inbred, rather homozygous strain of corn. Due to close breeding, the good characteristics of an old original variety of corn have been saved and should breeding experiments prove it to be fairly homozygous it would contain wonderful material for the plant breeder. It is now being used in tests and crossing projects at this Station.

Predisposition to Mental Disease

DIE VERANLAGUNG ZU SEELISCHE STOERUNGEN, by DR. FERDINAND KEHRER, professor of psychiatry and neurology in Breslau, and DR. ERNST KRETCHMER, professor of psychiatry and neurology in Tuebingen. Pp. 206, price $3. Berlin, Verlag von Julius Springer, 1924.

Probably no part of the study of mental heredity is more obscure than that of mental diseases. The accumulation of cases is slow; the diseases themselves are ill-defined and several distinct things are often lumped under one head. It is still too soon to produce a satisfactory treatise on the subject, but the authors of this book have done a service in putting out a critical and conservative review of the evidence available. Those who expect simple rules and brilliant generalizations will be disappointed; the book rather proves how little is really known about the subject.

The introductory theoretical part is perhaps the most interesting, as it deals with the confusion and vagueness into which the whole subject has too often fallen. The following parts take up the various kinds of mental disease in more detail.

The authors hold firmly to the postulate that mental diseases, having physical basis, are inherited (in so far as they are due to heredity) in the same manner as are ordinary physical traits. But there are—as would be expected—few if any mental diseases which follow a simple Mendelian scheme, and in many instances the data available are highly contradictory. *P. P.*

NOTES ON GONGORA GALEATA

CHARLES TORREY SIMPSON
Little River, Florida

SEVERAL years ago Professor Frances Grace Smith of Smith College sent me a small specimen of an epiphytic orchid from Guatemala, *Gongora galeata* probably. I at once planted it out—that is, I tied it to a rough-barked tree in my hammock—and it soon began to grow. It is now a fine large plant with stout, ribbed pseudobulbs and ovate shining leaves that are twenty inches long and nearly six wide, having five strong curved ribs that are prominent below. It blooms several times a year, sending out strictly pendent racemes of astonishing reddish or reddish brown flowers. No language that I can command, not even the best photograph, can give any adequate idea of these grotesque, almost whimsical structures.

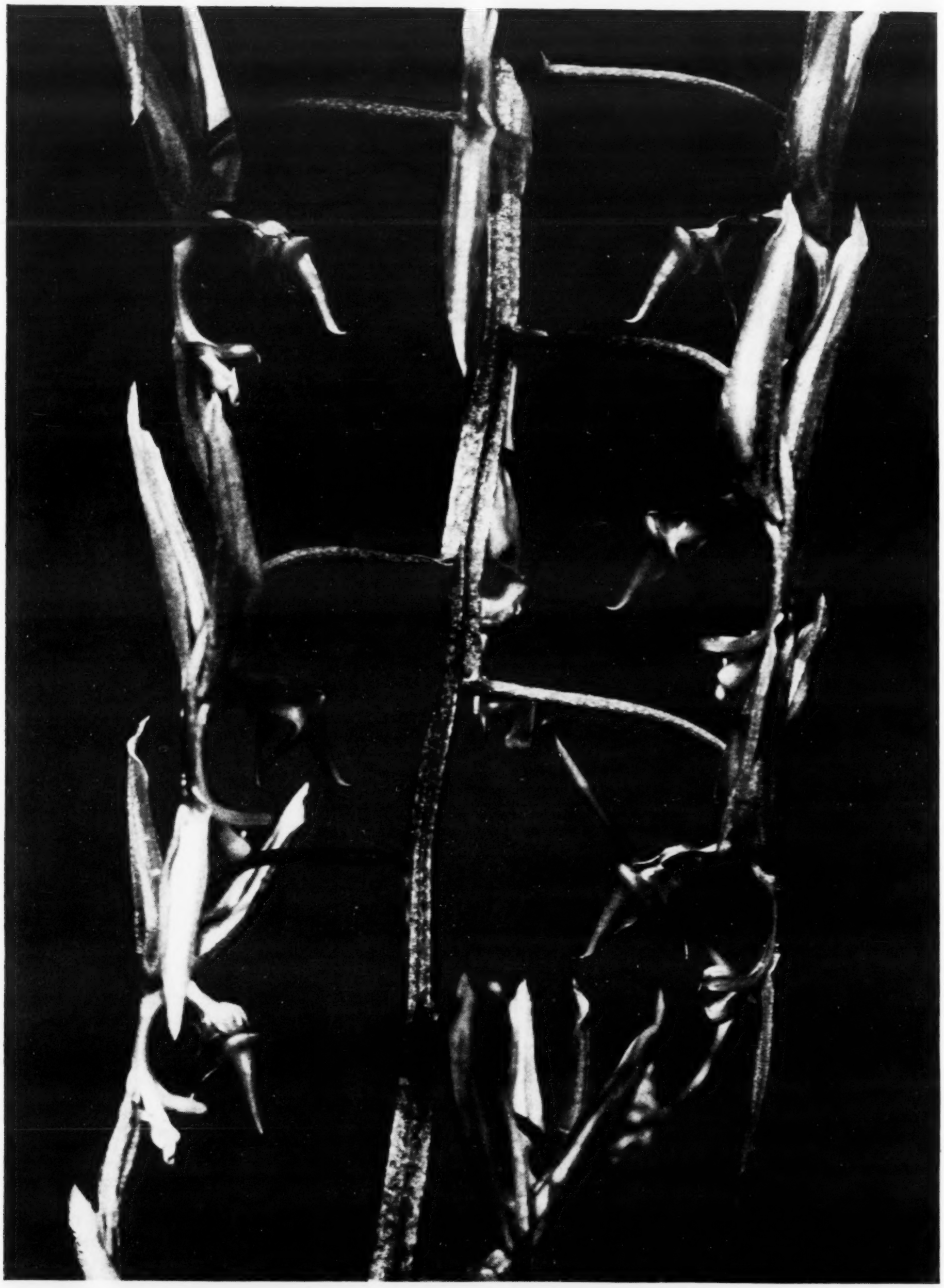
The plant itself clings tightly to the bark of the tree which is its host, the kinky, whitish roots finally forming a dense mass whose object seems to be not merely to hold the plant in place but to form an open mat which catches a variety of bits of twigs, dead leaves and insects, all of which decay and doubtless fertilize it, as is the case with many other tropical orchids.

Some time ago Dr. David Fairchild and Mr. P. H. Dorsett were at my place when this orchid was in bloom, and they took photographs of it. The former requested me to write some notes on it and send them to the JOURNAL OF HEREDITY. A few days ago it suddenly developed a raceme of buds, each of which was enclosed by the lateral sepals. All at once today, February 15, the entire chain of twenty-five flowers burst open, almost as if in answer to some signal. At the same time the air was filled with their sweet, powerful fragrance, which has a most decided hint of allspice. Owing to blooming in midwinter, perhaps, the raceme is only about two feet long, but in summer I have seen two at one time on the same plant fully three feet in length and bearing about forty flowers each.

The peduncle springs horizontally from the rachis of the raceme and curves outward and downward, gradually blending into the flower. The two lateral sepals become folded together, pointing upward and enclosing the flower stem; the third sepal is united with the column and extends to a considerable distance beyond it, the whole forming a continuous curve. The two petals are of delicate texture; they are arched and end in long points, which approach each other. The style, if I may call it that, is a sort of boat-shaped body with the concave side up, which comes out between the petals and has a direction almost parallel with the long solitary sepal.

I confess that this whole flower is a puzzle to me and that there are some things about it I cannot understand. The powerful scent would go to show that it called for some insect to come and cross-fertilize it. So far as I can see it has no nectar, but the greater part of the labellum is fleshy, and Dr. Cruger has observed, according to Darwin in his "Cross-Fertilization of Insects," page 168, that insects gnaw the labellum of *Gongora maculata*.

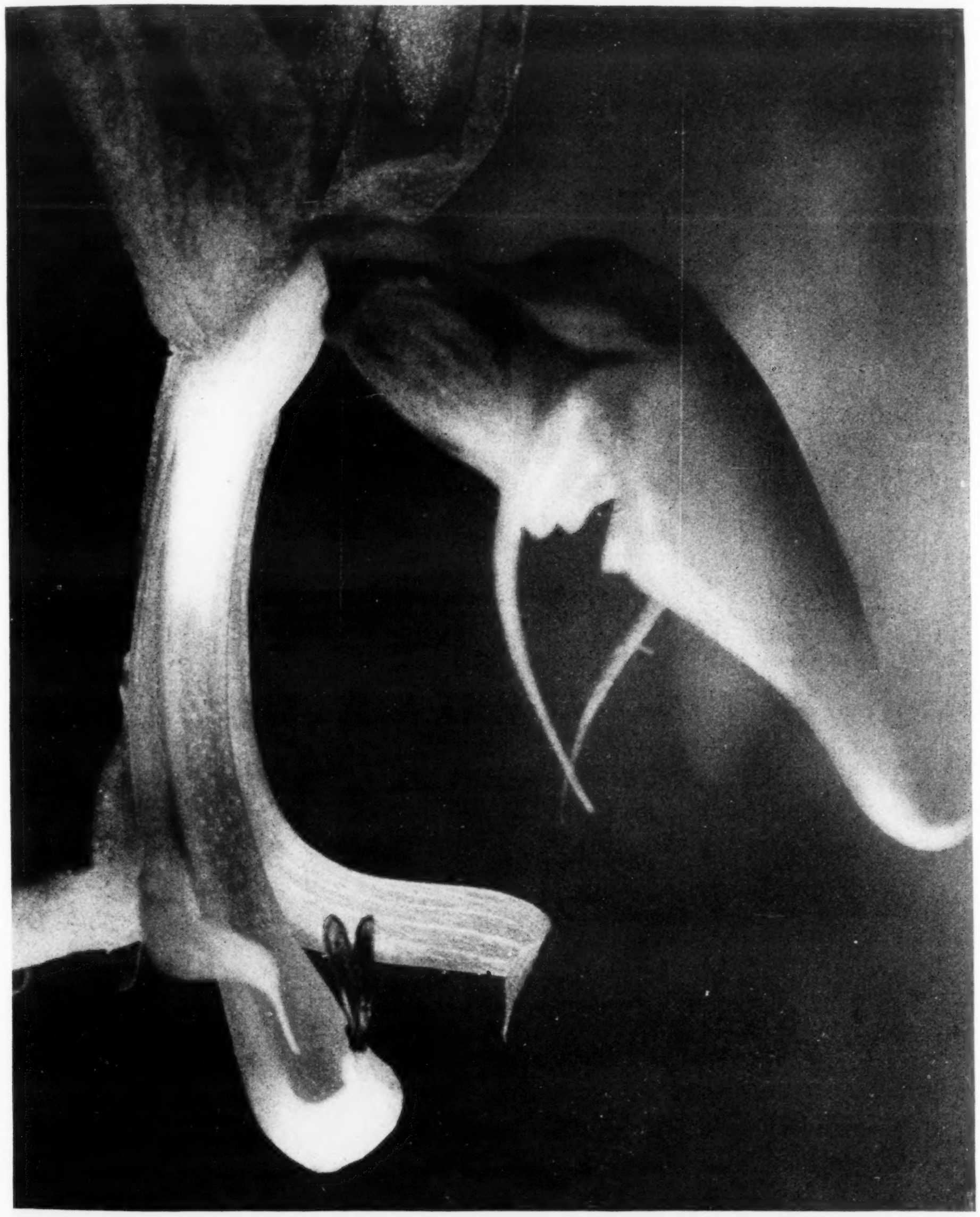
The only explanation I can offer of the manner of fertilization of this flower is that it is done by some small insect that relishes the fleshy parts of the complicated lip. Such an insect would probably alight on the solitary curved sepal, which is (as the pendent flower hangs) the lowermost part of the blossom. It crawls over the end of the stigma, which has a cap that completely covers the two elongated pollen masses, but which is turned back



FLOWER RACEME OF GONGORA GALEATA (?)

Figure 5

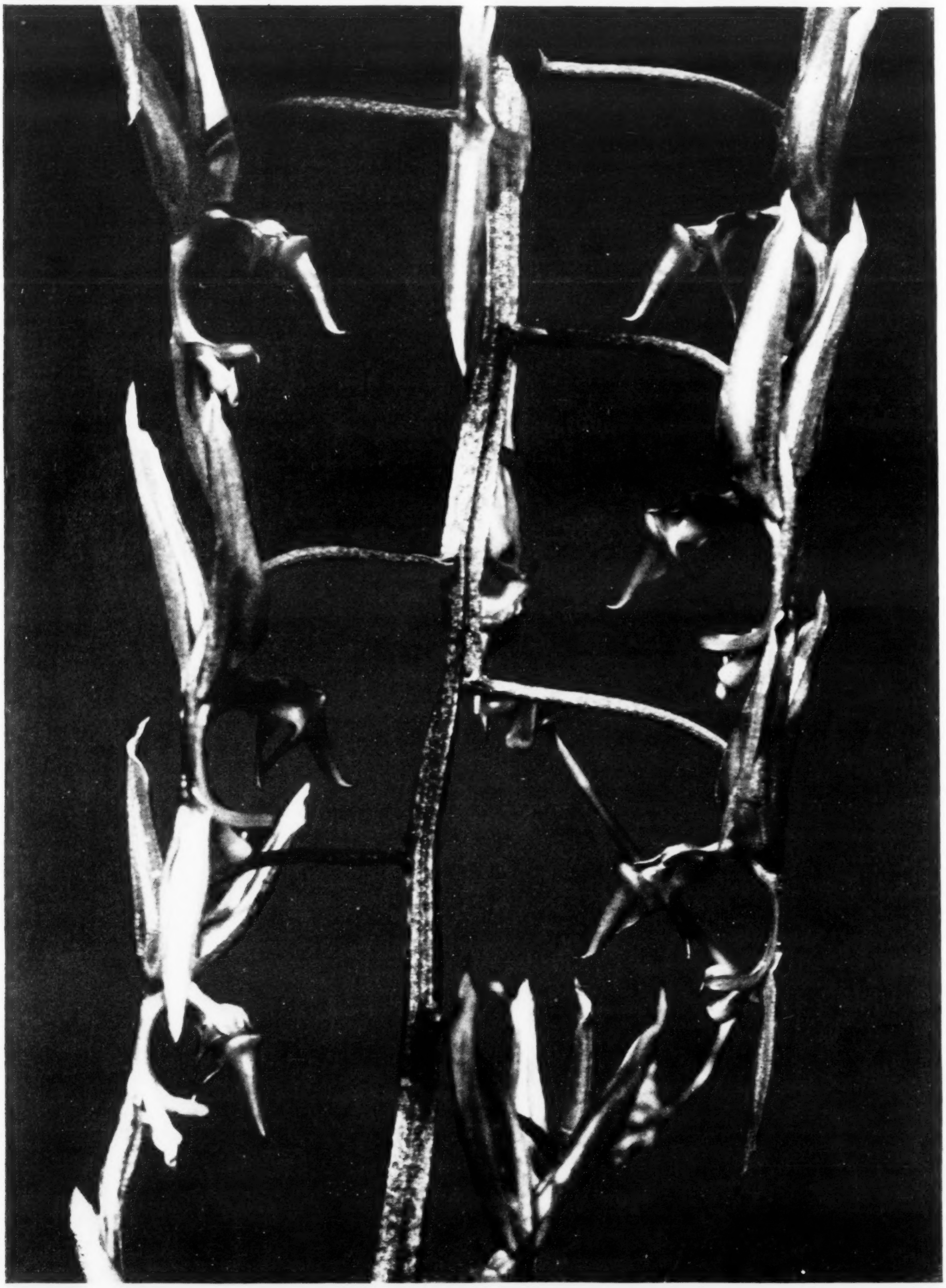
The entire raceme is from two to three feet long, the flowers are red or riddish brown. A portion of the pendant raceme and its grotesque flowers is shown here in its natural position



PART OF FLOWER OF GONGORA GALEATA

Figure 6

The labellum is shown at the upper right. The pendant column is at the left, and branching off from it the two petals, one turning to the right, the other to the left. Below these is the stigmatic sac, with the cap torn off and the two pollen masses standing erect on the tip. The cup-shaped cavity of the stigma will naturally hold any pollen that is brushed into it from the body of the insect, while the flower's own pollen is carried away as the insect backs out. Note the bristles on the labellum which keep the insect from rising.



FLOWER RACEME OF GONGORA GALEATA (?)

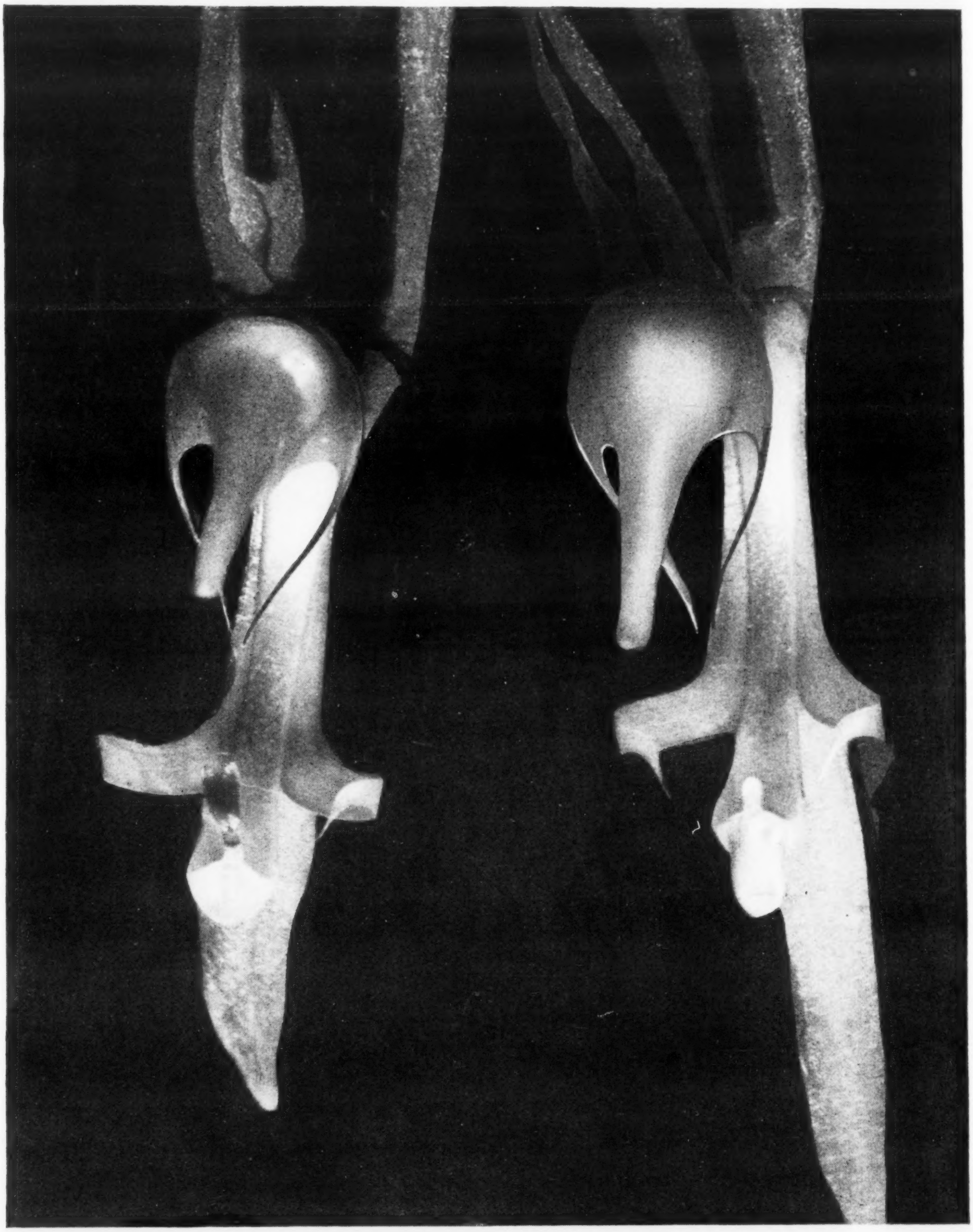
Figure 5

The entire raceme is from two to three feet long, the flowers are red or riddish brown. A portion of the pendant raceme and its grotesque flowers is shown here in its natural position

PART OF FLOWER OF GONGORA GALEATA

Figure 6

The labellum is shown at the upper right. The pendant column is at the left, and branching off from it the two petals, one turning to the right, the other to the left. Below these is the stigmatic sac, with the cap torn off and the two pollen masses standing erect on the tip. The cup-shaped cavity of the stigma will naturally hold any pollen that is brushed into it from the body of the insect, while the flower's own pollen is carried away as the insect backs out. Note the bristles on the labellum which keep the insect from rising.



PART OF TWO GONGORA FLOWERS

Figure 7

Each shows the end of the labellum above, with its bristles. Farther down are the two petals. The cap that covers the pollen masses is still in place on the right-hand flower. The flower at the left shows the pollen masses after the cap has been removed. The long isolated sepal is seen below.

so that the insect does not loosen it as it goes forward. It then gnaws at the base of the labellum, and as it does so its hinder parts, which carry pollen from another plant of Gongora, manage to loosen some of it, which falls into the boat-shaped stigma. The insect must be just the length that intervenes between the two points. The opening into the stigma is quite small, but perhaps large enough for the pollen to work through it. Having eaten its fill of the labellum, the insect backs out. There are two bristles from the labellum above that prevent it from arising; the curved petals give room for it to pass between them. As it goes backward it is sure to strike a spur that arises from the cap I have mentioned and pushes it off, at the same time uncovering the pollen masses that were under it. These masses instantly spring into a more or less erect position and the insect rubs strongly against them and they are either detached and adhere to it or at least give off more or less pollen which is carried away to the next flower. By this wonderful means the pollen of one flower is brought by the insect and deposited on the stigma of another, which does not yield up its own until after it is fertilized.

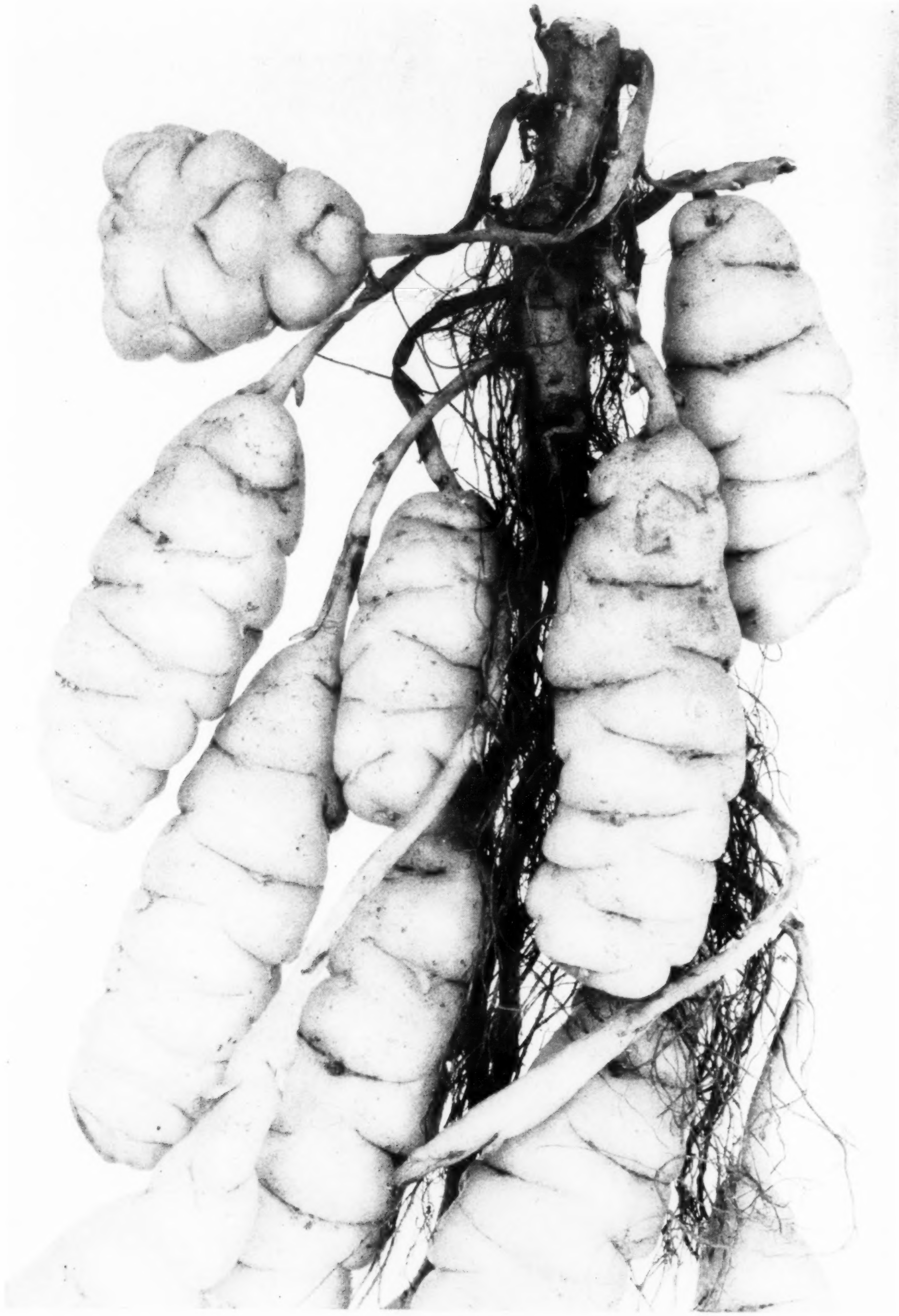
This flower seems like a wonderfully complicated but perfect machine, designed and built by a master inventor, and its whole purpose is to effect cross-fertilization through the agency of some perfectly fitted insect, a bee, perhaps. This is exactly of such a length as will reach from the base of the labellum, of which it eats the fleshy part, to the boat-shaped stigma, into which its pollen-laden hinder parts enter. The motion of this insect as it gnaws the fleshy food would naturally tend to dislodge pollen into the boat, where it would be in a position to work its way into the interior of the stigma. This is the only explanation I can make of this astounding flower. If constructed by an inventor we would say it was a marvellous machine, and to me it seems a proof of a universal intelligence—the pantheism of nature.

The Breast-Feeding of Infants

DER BIOLOGISCHE WERT DER MUTTERLICHE STILLPFLICHT, by HERMANN MUCKERMANN, S. J. Pp. 70. Price 50c. Freiburg, Herdersche Verlagshandlüng, St. Louis, Mo., B. Herder Book Co.

In this little booklet the Jesuit biologist gives a simple and convincing statement of the racial damage done by artificial feeding of infants, and the advantages both to mother and to child of breast feeding. Like most writers on the subject, however, he does not sufficiently take into account the fact that failure to nurse the child often argues a weak or impaired vitality on the part of the mother, and that the greater child-mortality among bottle-fed children reflects this sort of heredity, as well as the undoubted disadvantages of any other than the natural nourishment. The book, which is written for mothers rather than for students of biology, deals briefly with many biological topics related to childbirth.

P. P.



A SORREL ROOT CROP
Figure 8

The *oca* (*Oxalis tuberosum*) is one of the four high altitude root crops, less important than the potato, but more important than the *anyu* or the *ullucu*. The taste of the raw tubers is acid like sheep sorrel, but they become sweeter when exposed to cold weather. *Ocas,* like potatoes, are preserved by freezing and drying.

PERU AS A CENTER OF DOMESTICATION

Tracing the Origin of Civilization Through the Domesticated Plants

(Continued from the February Issue)

O. F. Cook

U. S. Department of Agriculture

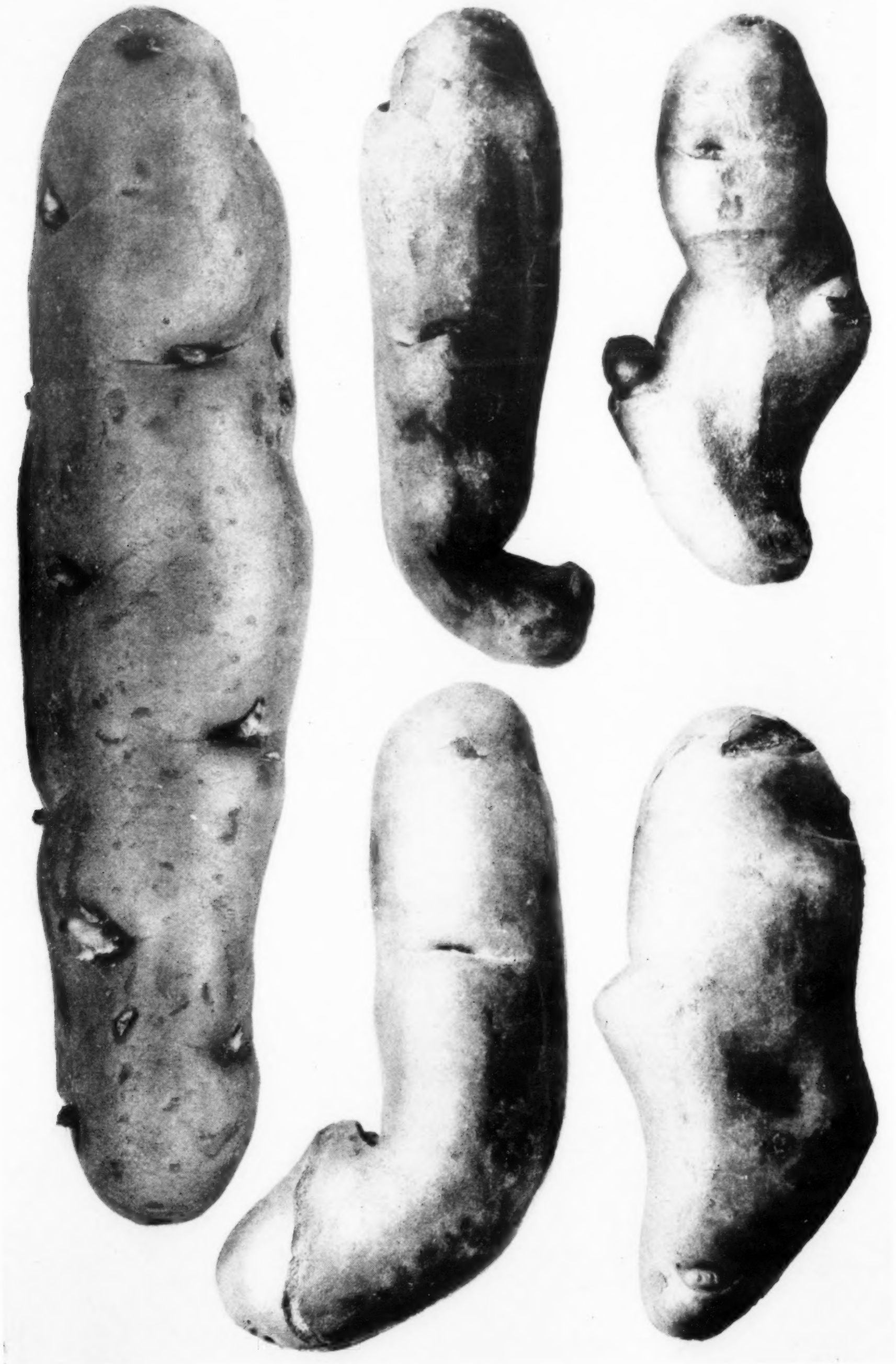
A TERRACED VALLEY IN THE ANDES

Figure 9

This is a view of the valley above Ollantaytambo, on the eastern side of the Andes, one of the chief centers of pre-Inca culture in Peru. The entire valley bottom was reclaimed by the ancient colonists, who must have planned and laid out the terraces before the land was occupied. Note the ruined building high up on the cliff on the right. The purpose for which this was used is not known. Possibly it was a storehouse, rather than a nunnery, as has been suggested. On the steeper slopes in the middle distance can be seen the almost obliterated remains of some of the ancient terraces that have been long abandoned.

Endemic Crop Plants of the Peruvian Region

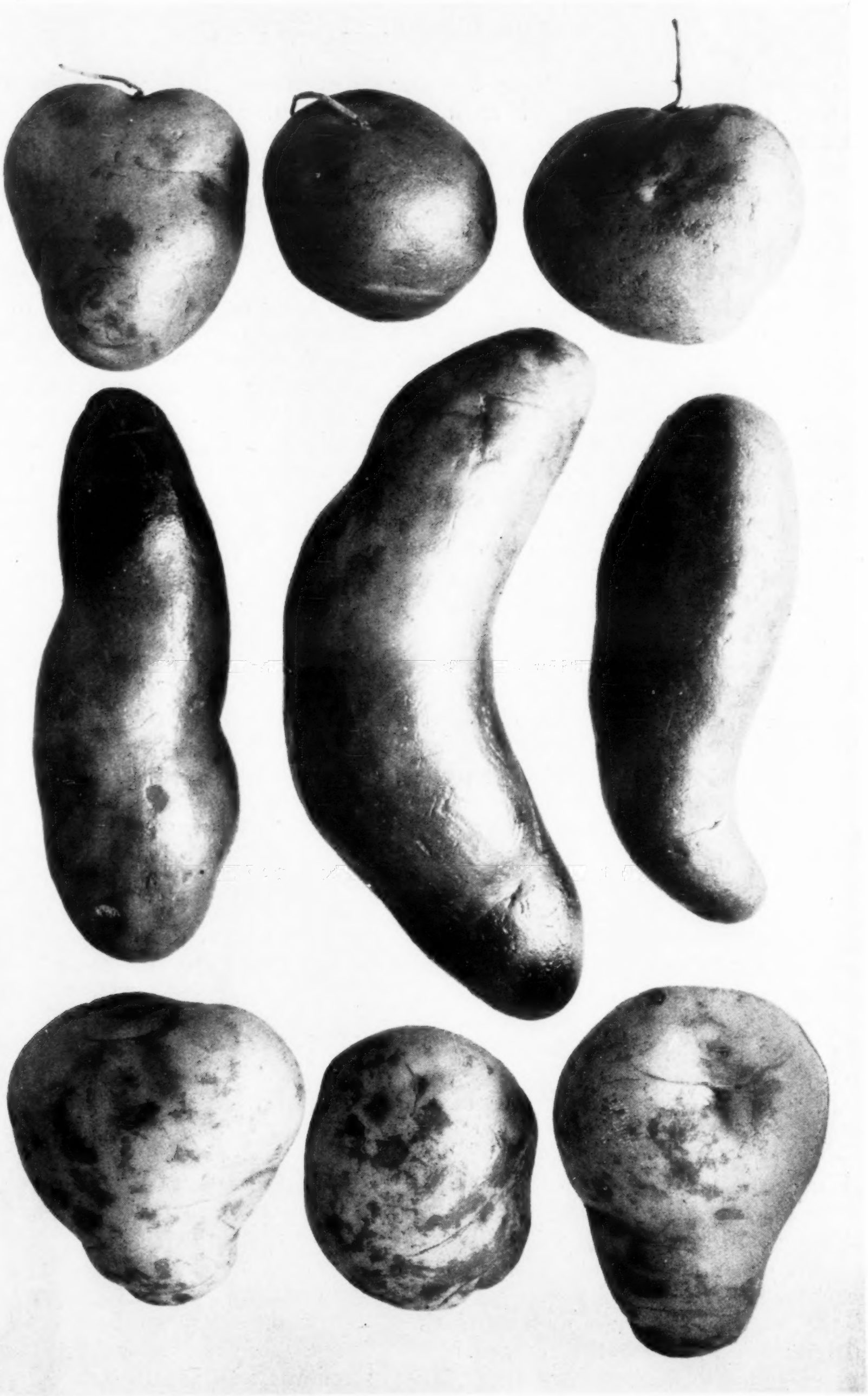
ORIGINS and places of domestication are difficult to trace with plants that are widely distributed in cultivation but of which no recognized wild type is known, as in the case of maize, and difficult also with plants that escape readily from cultivation and grow spontaneously in different parts of the world. But in Peru there are many domesticated plants whose origin is hardly to be questioned, since their cultivation has not extended to other regions. Also most of the endemic crop plants of Peru are to be found growing wild, or are closely related to wild species of the same region. Obviously, there is



PERUVIAN POTATO VARIETIES

Figure 10

The potato is the most valuable of the gifts that the ancient Peruvians made to the agriculture of the world. One year's potato crop amounts to from four to six billion bushels, which represents in money value probably far more than the treasure taken from Peru at the time of the conquest. In spite of this, the potato is not an unmixed blessing, for by making possible a greatly increased population in northern Europe it is to be regarded as one of the contributing causes of the World War.



ROOTS OF THE PAPA LISA

Figure 11

These are not potatoes, but represent three varieties of the *ullucu* or *papa lisa*, a root-crop of the highlands of Peru. The plant is related to the familiar Madeira vine, of the family Basellaceae. *Papa lisas* are usually cooked with potatoes as an ingredient of soups or stews. The varieties differ greatly in shape and size as well as in color, ranging from white to yellow, pink, and red. (Natural size.)

no reason to seek elsewhere for the center of domestication of such endemic species. Certainly no other part of America can compete with the Peruvian region in the number of endemic crop plants, some of them prominent, like the potato, the chirimoya and the coca or cocaine plant, while many others are scarcely known outside of Peru.

The significance of the endemic plants, as marking a center of domestication, has been overlooked. With some of the special writers on Peru, the distinctive local products have almost monopolized attention, while the other plants that were shared by Peru with other parts of tropical America have been disregarded as though having no relation to the endemic series. Though nobody would deny that the endemic crop plants were domesticated in the Peruvian region, the prepossession toward Mexico makes it possible to assume that the widely distributed plants, such as Indian corn, sweet potatoes, peppers, and peanuts were carried to Peru from Mexico or from the West Indies. To some writers this idea, that the plants were carried to Peru, has been suggested by the fact that the early Spanish explorers learned the names and uses of many of the American crop plants before Peru was discovered, and several such names were carried to Peru, already incorporated in the Spanish language.

Native Peruvian Plant Names

Since the identification of genuine native names is probably the best evidence of the existence of the plants in Peru in pre-Spanish times, it is worth while to place on record a list of the native Peruvian names of the cultivated species, mostly derived from the so-called Quichua or Inca language. Some of the native Peruvian plant names have been replaced almost completely by West Indian or Mexican names brought in by the Spaniards, like *maiz* for Indian corn, *mani* for the peanut, and *camote* for the sweet potato, but the native language of Peru is still spoken by millions of people. Most of the Peruvian names that were recorded in the early days by Cobo and other writers are still current, at least locally, in some of the valleys of the Andes. No doubt some names remain to be discovered, and other species or varieties of plants probably are hidden in remote valleys.

Some of the names are handed down from early Spanish writers, and some have not been found in previous publications, but seem to have been recorded for the first time in 1915, during a joint expedition of Yale University and the National Geographic Society, in cooperation with the Department of Agriculture. Some plants have several names, referring to different varieties or to different parts that are used, while some plants that appear to be thoroughly indigenous are yet to be associated with genuine native names. The number of native cultivated plants may be estimated safely between seventy and eighty species. The series no doubt is incomplete, and the applications of some of the names are rather uncertain, but at least a preliminary list should be available as a basis of further discussion. The list no doubt could be extended greatly on the side of ornamental and medicinal plants, shrubs and trees, many of which have a status of partial cultivation, but only the more important of such species are included. Similarity to Mexican names may be noted in some cases, as *achihuiti, lacayote* and *suchi*, but the origins need to be definitely determined. Names of several types of beans, peppers, squashes, gourds and passion-fruits are included, but not the names of the many varieties of potatoes and other root-crops, which probably would double the list.

List of Names of Domesticated Plants in Peru

Peruvian Name. *Genus.* *Spanish and English Names.*

Abinca (Cucurbita) squashes with hairy seeds.
Achira (Canna) a warm-temperate root-crop.
Achocjche (Cyclanthera) cayguas, a climbing vine with an edible fruit.
Achupalla (Ananas) pina, pineapple.
Ajipa (Cacara) jicama, yam-bean, a root-crop eaten raw.
Amarucachu (Polianthes) tuberose.
Amancay (Amaryllis) a favorite flower.
Ancara (Lagenaria) calabaza, calabash.
Anyu (Tropaeolum) a high altitude root crop.
Apichu (Ipomoea) camote, sweet potato, the sweet varieties.
Apincoya (Passiflora) grandilla, the large passion-fruit.
Aricona or *Aricuma* (Polymnia) see llacon.
Arracacha (Arracacia) apio, a temperate-region root-crop.
Ayauasca (Banisteria) a low-land intoxicant.
Ayrampu (Opuntia) small cactus used for dye.
Cachuma or *Cachun* (Solanum muricatum) pepino, an edible fruit.
Canyihua (Chenopodium) a high-altitude seed crop.
Cantu (Cantua) flor del Inca, flower of the Inca.
Caya (Oxalis) also written *kahuy,* dried ocas.
Chachacoma (Escallonia) a high-altitude tree, the wood used for carving.
Chinchi (Capsicum) aji, cayenne pepper.
Chirimoya (Annona) a temperate-region fruit.
Chonta (Guilielma) a palm with edible fruits, some varieties seedless.
Chuchao (Frucraea) an important fiber plant, generally growing wild.
Chunyo (Solanum) papa, potatoes frozen and dried black.
Chuy (Phasaeolus) frejol, bean.
Coca (Erythroxylum) the cocaine shrub.
Cocopa (Solanum) dried potatoes.
Cohuacho (Cucurbita) squashes with small white seeds.
Coimi (Amarantus) see also quichuicha.
Cullash (Schinus) mulli, pepper tree.
Cumara (Ipomoea) camote, sweet potato, the starchy varieties.
Cuyuy (Ruda?) used as pot-herb.
Huacatay (Tagetes) used as pot-herb.
Huantuc (Datura) used as intoxicant.
Huayau (Salix?) sauce, a fastigiate willow often planted.
Huillca (Piptadenia) a leguminous tree, medicinal and intoxicant.
Huitocj (Genipa) a tree of the warm eastern valleys, valued as a medicine.
Inchis (Arachis) mani, peanut, with only one seed in a pod.
Jataco (Amarantus) seed-crop of temperate regions.
Lacayote (Cucurbita) squashes with black seeds.
Lambran or *Ramran* (Alnus) aliso, alder.
Marcu (Ambrosia) used as pot-herb.
Masasamba (Annona) guanabana, soursop.
Matti (Lagenaria) the bottle gourd.
Moray (Solanum) potatoes frozen, soaked and dried, white like chalk.
Mulli (Schinus) "pepper tree" of California, native of the Andes.
Nucjchu (Salvia) with pendent scarlet flowers.
Oca (Oxalis) an important root-crop.
Pacay (Inga) a tree with edible pulp surrounding the beans.
Pacjpa (Furcraea) wrongly called "maguey."
Pallar (Phaeaeolus) Lima bean.
Palta (Persea) aguacate, avocado.
Pamuco (Crescentia) the calabush tree.
Pante (Polymnia?) a rott crop similar to llacon, but smaller.
Papa (Solanum) papa, Irish potato.
Papaya (Carica) papaya, pawpaw, two species planted.
Payco (Chenopodium) used as a pot-herb.
Pirca? Lycopersicum and Cyphomandra) tomato, cultivated and wild species.
Piris (Capsicum) a small variety.
Pischic (Sambucus) sauco, elder-berry, a tree of the eastern Andes.
Pisonay (Erythrina) tree with scarlet flowers.
Poro or *Puru* (Lagenaria) the bottle gourd.

Purush (Passiflora) a passion-fruit.
Purutu (Phasaeolus) frejol, bean.
Quenuar (Polylepis) a high-altitude tree.
Quihuicha (Amarantus) a temperate-region seed crop.
Quinoa or *Quihina* (Chenopodium) a high-altitude seed crop.
Quisuar (Buddleia) a high-altitude tree.
Racacha (Arracacia) see arracacha.
Rocoto (Capsicum) chili, cayenne pepper.
Rucma (Lucuma) see lucma.
Rumu (Manihot) yuca, cassava, the chief tropical root-crop.
Sahuinto (Psidium) guayava, guava.
Sapallu (Cucurbita) calabaza, squash, many varieties, also wild.
Sara (Zea) mais, Indian corn, Cuzco type, with sweet and pop varieties.
Sara sara (Paspalum) maisillo, a grass cultivated for forage.
Sayri (Nicotiana) tobacco, also called *camasayre*.
Suchi (Plumieria) frangipani, a small ornamental tree.
Sulloco (Sapindus) soap berry.
Tara (Caesalpinia) *C. pectinata*, used for dye.
Tarhui (Lupinus) altramuz, cultivated for its seeds, which are eaten.
Tintin (Tacsonia) a passion-fruit, broadly rounded, flattened at the end.
Tumbo (Tacsonia) a passion-fruit, long-elliptic, pubescent, sour.
Uchu (Capsicum) general name for peppers.
Ullucu (Ullucus) papa lisa, a root crop.
Uncucha (Xanthosoma) a tropical root-crop, also dried to make chunyos.
Unguna (Curcuma?) a root-crop.
Usum (Prunus) capuli, the Andean cherry.
Utcu (Gossypium) algodon, cotton, the "rough Peruvian" type.
Yacon (Polymnia) see llacon.

Crop Plants of Extra-Peruvian Origin

Though it would not be reasonable to ascribe definitely to the Peruvian region all of the plants that were shared by the ancient Peruvians with other parts of America, neither is it reasonable to assign these plants to other regions without requiring evidence that they did not come originally from Peru. The only safe way is to disregard temporarily the plants that were shared by Peru with the other regions, and give our attention to plants that seem not to have been known in the Peruvian region in ancient times, and thus may be considered as extra-Peruvian. From the paucity of such extra-Peruvian species it appears that no other center of plant domestication was comparable in importance with the Peruvian region.

Reckoning seventy species of plants as cultivated in Peru in pre-Spanish times, and at least half of these as definitely endemic or confined to that region, the status of Peru as a center of domestication would seem to be established.

Other Centers of Domestication

The highest developments of the culture of extra-Peruvian plants undoubtedly were those of the cacao in Guatemala and southern Mexico, and of the pulque agave in the Mexican table-land. The Central American avocado no doubt is a native tree but is scarcely to be considered as a cultivated crop, among the native population. Other Central American domestications were garden plants, as chayote (Sechium), chia (Salvia), and the chiltomate, a species of Physalis. Calathea and Dioscorea may have been cultivated to a slight extent in the West Indies, though this is doubtful. The cassava, sweet potato, and yautia (Xanthosoma) were grown in the West Indies, and arracacia has been found recently in the mountains of northern Haiti.

Only two secondary centers of domestication are indicated, one perhaps in the Maya districts of Guatemala to account for cacao which is a low-land tropical tree, and another in the table-lands to account for the pulque agave and other plateau cul-

tivations. But all of the Central American or Mexican domestications appear to be secondary and incidental to the existence of people who lived by milpa agriculture as in the lower valleys of Peru. The table-land agriculture of Peru was the striking, peculiar development, while the agriculture of the lower elevations was essentially the same in Peru as in other parts of tropical America. Nowhere in America does there appear to have been an extra-Peruvian agriculture, where people subsisted regularly or chiefly on crops that the ancient Peruvians did not have.

Of course, it is possible to assert that the agriculture of the lower valleys of Peru came from Mexico or elsewhere, and received a special elaboration in Peru, on account of peculiar conditions, but certainly the question should not be prejudiced in advance by casual assertion. The conditions in Peru should be studied to see whether they were specially favorable for domestication, and for developing specialized agricultural arts, whether more of the ancestral forms of the cultivated plants can be found in the Peruvian region, and whether the movements of the native races radiated from Peru as a center, or from some other region. Such questions may be followed by students of the physical characters, languages, customs, arts or ancient remains of native peoples of South and North America.

Conditions of Domestication in Peru

Domestication should be studied from the standpoint of biological or ecological conditions, and especially the primary domestications of food-plants. That so many plants were domesticated in Peru suggests that the people must have had a special talent for agriculture or that the conditions in some way were especially favorable. Such conditions may be found in hundreds of narrow precipitous valleys, often a mile deep, cutting through the highest chain of the Andes.

Primitive people who might enter and establish themselves in such valleys would find their movements restricted and their means of subsistance narrowed to the products of one district. Thus there would be ample opportunity and incentive for careful search and trial of any food possibilities of the native flora, and for the taking of the first step in cultivation, by pulling the useless *cora,* which we call weeds, to let the food-plants grow. Greater pressure on the means of subsistence would carry the people gradually to habits of more intensive cultivation, by clearing the ground completely of other growth and using sprouts, tubers or seeds to propagate the useful species.

Among the historical writers, Payne was almost alone in developing a practical idea of the conditions that would be favorable for leading a primitive people to domesticate plants and adopt the habits of a settled agricultural existence.

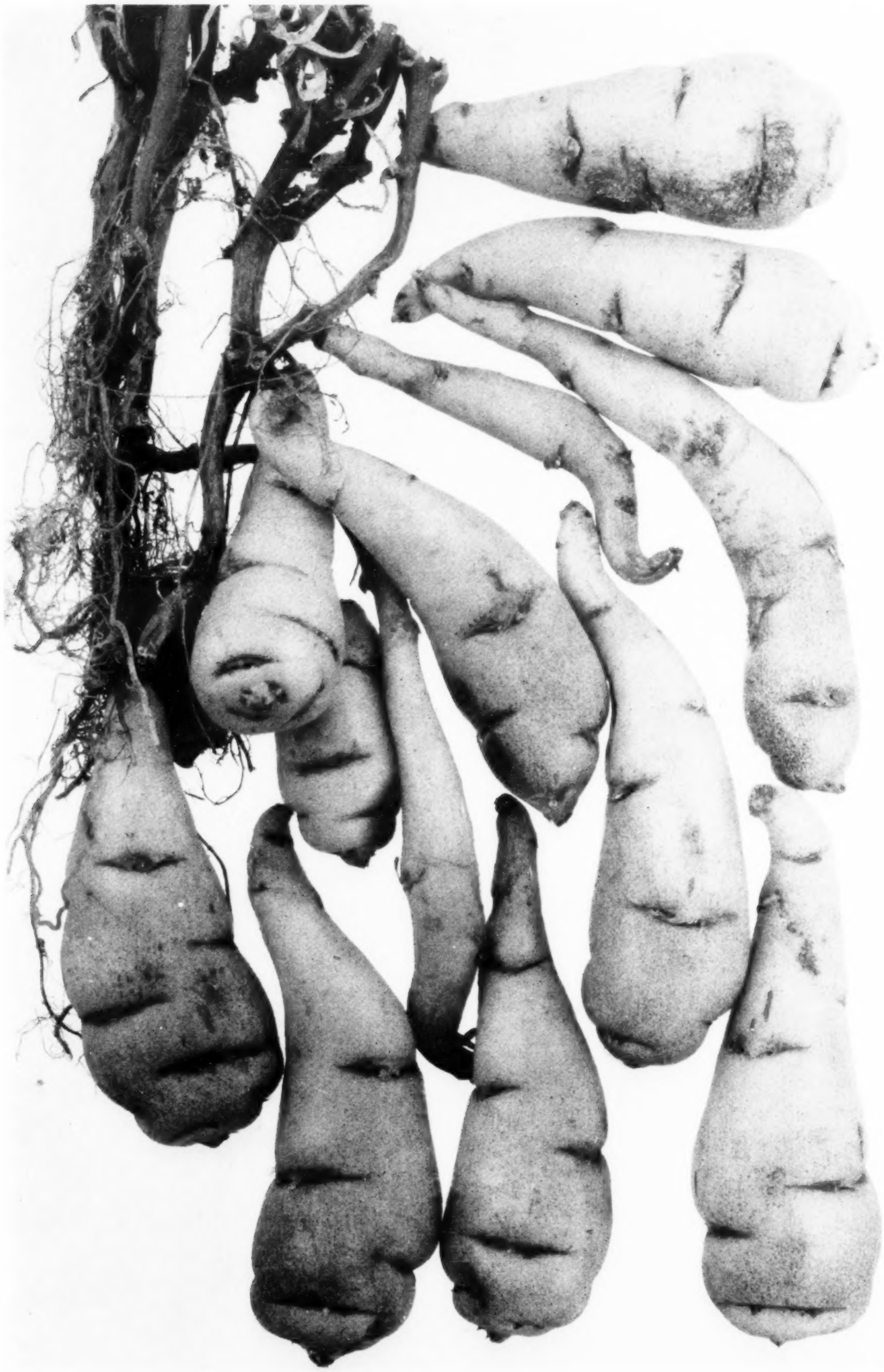
"In order that cultivation may become permanent there must be a concurrence of the opposite conditions—a concentration of population within separate and limited areas, separated, it may be, from each other by tracts which yield no food at all: . . . ."

These conditions are met in the most definite and striking way in the narrow deep valleys of the eastern Andes. Payne, however, was somewhat misled by the idea of a primitive pastoral state, and considered the table-lands as the original scene of development of the Peruvian system. In contrast with the deep-cut valleys of the eastern Andes the Peruvian table-lands are a succession of broad gently sloping valleys, readily accessible open grassy country, not favorable to agriculture and not affording the definitely circumscribed conditions that would lead a wandering shepherd people to adopt a settled existence. Though the ancient civilization attained a higher development in the upper valleys and on the table-lands, these lower valleys may have witnessed the first steps of progress

AN EDIBLE CANNA

Figure 12

This plant, called *Achira* in Peru, is much like our familiar ornamental varieties of canna, but with rather small flowers. The roots are boiled and have a sweetish taste, but are very fibrous and much inferior to sweet potatoes.



A NASTURTIUM ROOT CROP

Figure 13

The *anyu*, a root crop grown at high altitudes, with the potato, the *oca* and the *ullucu*. The plant is a species of Tropaeolum closely related to *Tropaeolum majus*, the common Nasturtium of our gardens. (Natural size.)

toward an agricultural state. Notwithstanding the wide range of conditions and the numerous plants that were domesticated, the system of agriculture seems continuous and complete, as though the same race of people had adapted themselves gradully to the conditions of the higher valleys, many of which appear to have been planned and developed as reclamation projects.*

Domestication of Animals in Peru

In addition to the domestication of numerous high-altitude crop-plants, at least four kinds of animals were domesticated in ancient Peru, the llama, the alpaca, the guinea-pig (*cuy* or *cohui*) and two or more species of dogs. The llama and alpaca furnished wool and served as pack animals, the only native beasts of burden in the New World. The *cuys* are kept in the houses and seem to be more thoroughly domesticated than any other animal. Only the *cuy* is generally distributed among the natives of Peru, the llamas and alpacas being kept only at the higher altitudes, seldom below 12,000 feet. A species of duck was also probably domesticated and the cochineal insect was used as a dye, which still appears in the native markets under the name *macnu*.

Elsewhere in America the only regular domestication of an animal seems to have been that of the turkey in Central America, aside from the dogs which were generally distributed, and may have been adopted in a pre-agricultural age.

The llama and alpaca may be only different varieties of the wild huanaco. Though members of the camel family, their habits and uses are closely analagous to those of sheep in the Old World, to furnish wool and meat. The male llamas also carry burdens, but do not serve as draft animals, so that all of the agricultural work is done by hand, even in the higher altitudes where tough sod-land is broken by hand labor for planting potatoes.†

The greater resemblance to European agriculture resulting from the use of domestic animals and of woolen clothing in the high altitudes of Peru has led Payne and several other writers to consider the Peruvian table-lands as the original seat of agriculture in America, or at least in South America. The general tendency of historical writers has been to feature the table-land agriculture, instead of considering it as a specialized development of the more primitive systems that are still employed in the lower valleys of Peru, as in other parts of tropical America.

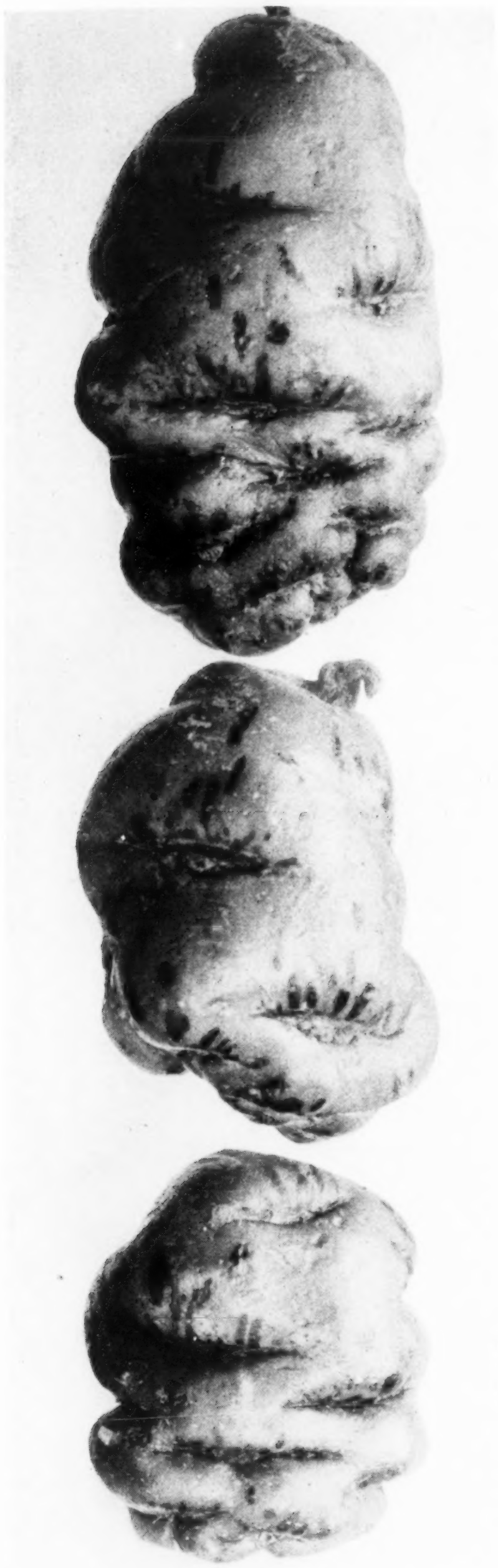
Agricultural Arts of Peru

In addition to the domestication of plants and animals, several agricultural arts were highly developed by the ancient Peruvians. The ancient remains found in the Peruvian region, the accounts written by the early Spanish historians, and the evidence afforded by the Quichua language, leave no doubt that knowledge of the behavior and requirements of the plants, and skill in the agricultural arts, were carried to a more advanced state in Peru than in any other part of America. With regard to some features it is doubtful whether a higher development of agriculture has been attained in any other part of the world. Only a few regions present so wide a range of conditions, nor have such unfavorable natural conditions been utilized in other countries to any such extent as in Peru.

Building of Terraces and Irrigation Works

The nature and extent of the agricultural works of the ancient Peruvians have not been understood or appreciated. The narrow terraces of the steeper slopes have been described by many writers, while the broader terraces on the floors of the valleys have been overlooked. Many square

*Staircase Farms of the Ancients. *National Geographic Magazine*, May, 1916.
†Foot-Plow Agriculture in Peru. Smithsonian report for 1918, Pages 487, 491.



A STRIPED VARIETY OF ANYUS

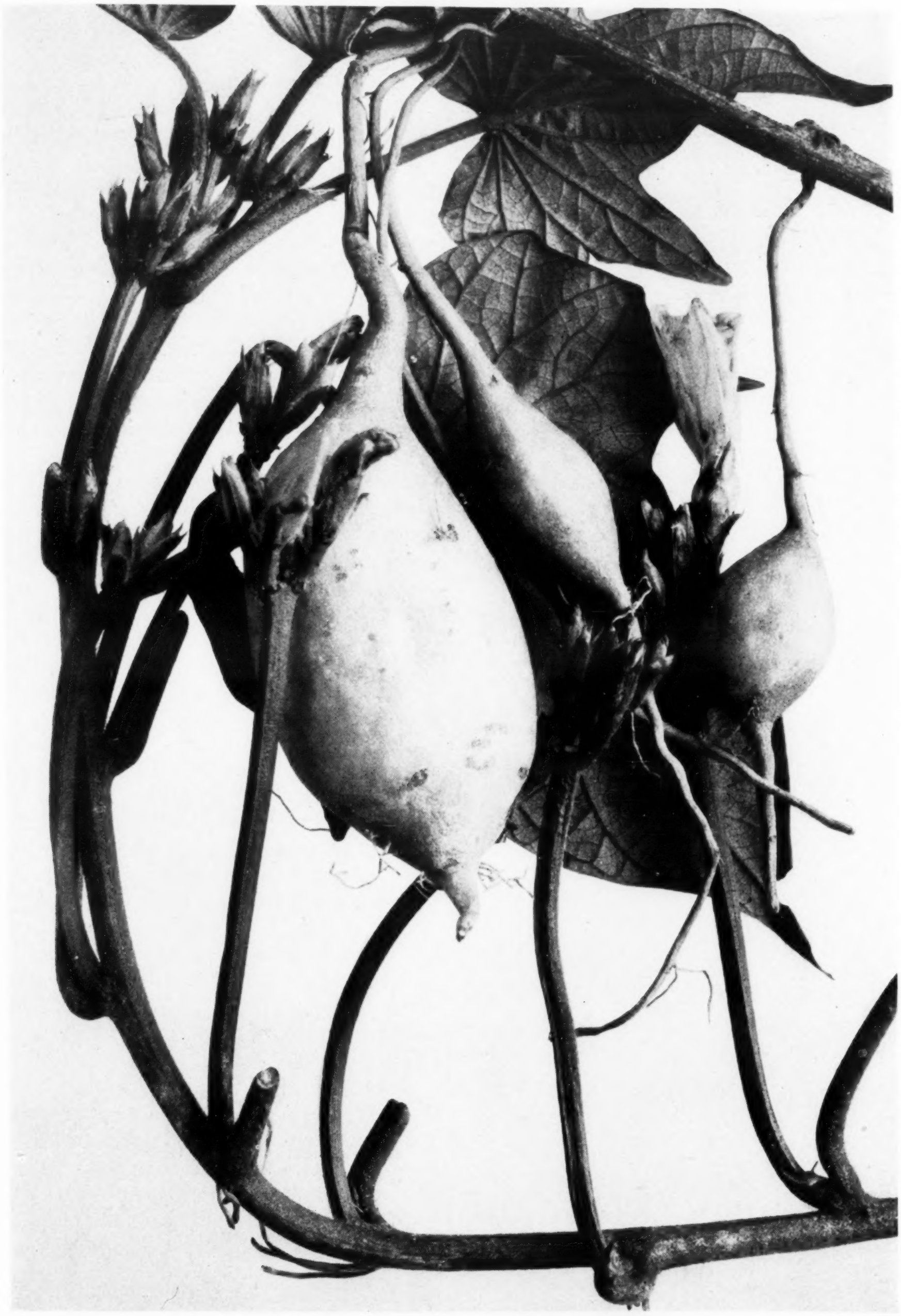
Figure 14

The tubers are thickened and the stripes are purple.

miles of the valley floors have been terraced and the work is so extensive that its artificial character is difficult to credit even in the presence of the facts. Travellers have supposed that the retaining walls were merely stone fences although the fields are on different levels. Many of the retaining walls are of the primitive megalithic type and are marvels of persistent well-organized labor. Stones of great size, weighing many tons, were fitted together with an incredible nicety whose mechanical explanation is still to be found.

Engineering talent was displayed also in the arrangement and grading of the terraces, in straightening and confining the rivers, and in carrying irrigation aqueducts along the precipitous slopes and narrow crests of the mountains, often for many miles. In some districts all of the agricultural lands are of artificial construction and represent an amazing expenditure of labor, second to none of the so-called "Wonders of the World" in the Eastern Hemisphere. The terrace builders were skilful not only in laying up walls, but in the placing of the artificial soil which has retained its fertility after centuries of cultivation. Thus the ancient agriculture of Peru has solved the problem of soil conservation and presented a complete contrast with the wasteful systems that are used at present in many parts of the world.

It is of interest from the standpoint of human evolution that this extreme specialization of the art of agriculture was attained in the prehistoric period, probably many centuries earlier than the Inca empire that Pizzaro conquered. The highest development of the terrace building art was not in the high plateaus, where such terraces were not needed, but in the valleys of the Eastern Andes where the climate was more genial but the soil and the water had to be supplied artificially. From the regular laying-out of the fields it is evident that the eastern valleys were developed as reclama-



A SWEET POTATO IN FLOWER

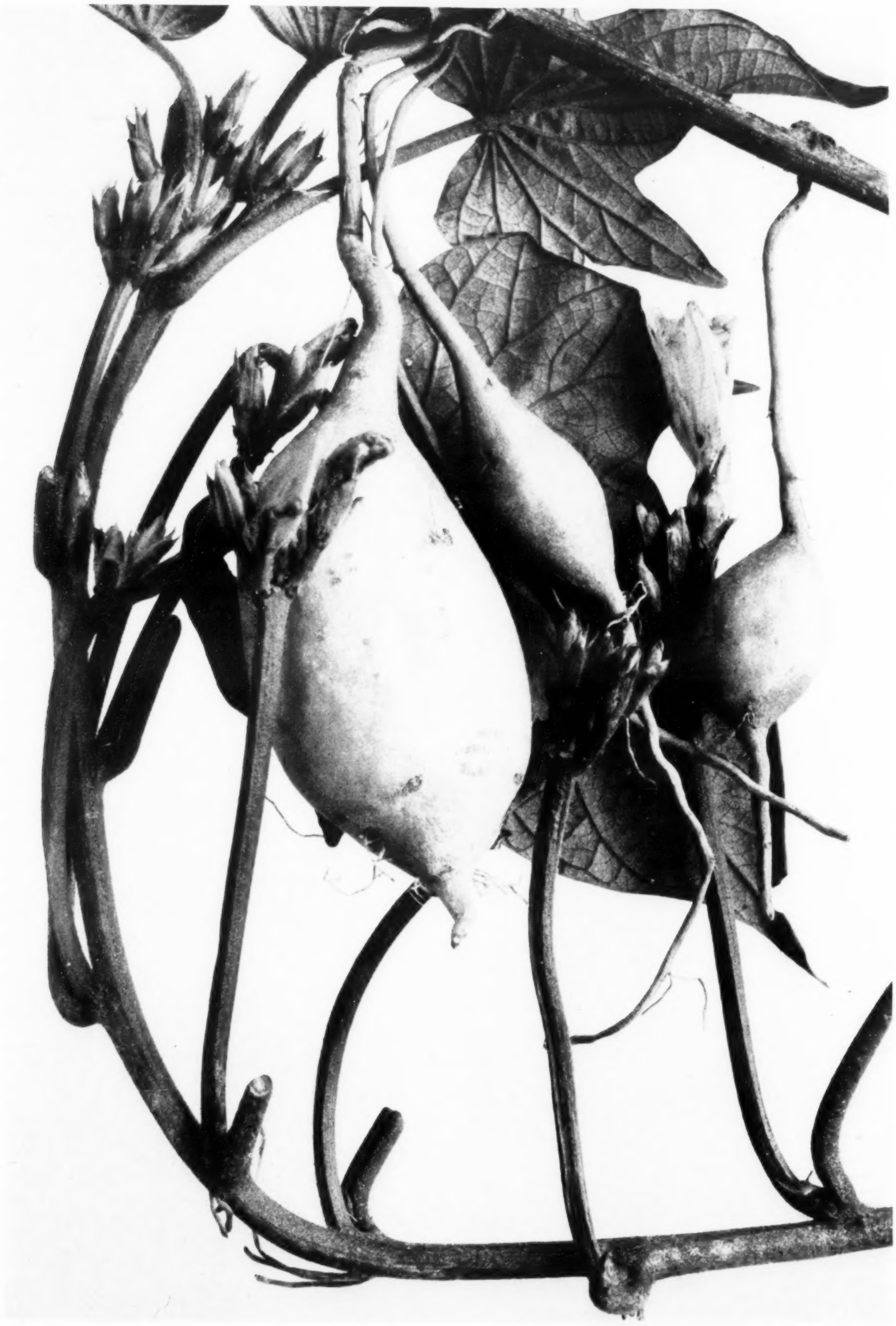
Figure 15

The native name is *cusi-cumara,* said to mean "long cumara." The same name *cumara,* is found widely distributed in the Pacific islands, where the sweet potato appears to have been of greater importance as a food crop than in other parts of the world. The bottle gourd was also shared by the Peruvians and the Polynesians before the coming of Europeans, though without such similarity of names. Gourds might conceivably have floated across the Pacific, to take root without the agency of man, but the sweet potato and its name could hardly have been carried in this way.

ROOTS OF THE LLACON

Figure 16

These roots, which resemble the Jerusalem artichoke, are produced by a species of Polymnium, a tall composite herb like a sunflower. The flesh of the root is white and crisp. The *llacon* (or *yacon*) and the *ajipa* are two root crops that are eaten raw. All the others require cooking.



A SWEET POTATO IN FLOWER

Figure 15

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INCA STOREHOUSES

Figure 17

A line of sixty Inca storehouses at Pinyasniocj near the pass of Panticalla, between the Urubamba and the Lucumayo valleys, at an altitude of about 12,000 feet. The storehouses are built in twenty separate units, with the walls of the sections only a few inches apart. Some of the storehouses have been crushed by huge boulders rolling down the steep slopes. The survival of several kinds of trees in this valley is ascribed to the protection afforded by the boulder-covered hillside.

tion projects, with the work organized and planned, instead of being done by individual settlers.

Terrace agriculture is not only a means of utilizing steep or broken land, otherwise not capable of cultivation, but is also of interest as representing a permanent system of agriculture, in contrast with our ways of using the soil. The ancient Peruvians were soil-makers, while much of our farming is destructive. By means of terracing, the soil is drained and kept in place so that the fertility is not lost, but may continue to increase as it does in uncultivated lands. The terraced lands of the valleys of the eastern Andes undoubtedly have been cultivated continuously for many centuries and are still very productive. The great antiquity of the terrace system thus has a special significance as showing the possibility of a permanent agriculture, which is the necessary basis of a permanent civilization.

Weaving of Cotton and Wool

The textile art also contributed to the occupation of the high valleys and table-lands, and was developed more highly in Peru than elsewhere in America. Cotton was grown in the lower valleys, and used extensively, while in the table-lands three kinds of wool were spun and woven, coarse wool from the llama and fine wool from the alpaca, while the material for the very finest work was from the fleeces of the wild vicunas, which were driven together and plucked periodically. Many ancient masterpieces of weaving have been found in the graves of the coast region, including elaborate pictorial tapestry which might be compared in execution, design, and conventionalized sym-

PERUVIAN POTATO VARIETIES

Figure 18

These are from the region of Cuzco and Ollantaytambo. The colors and textures of the tubers are as varied as the shapes and sizes. Some varieties are deep purple under the skin and others purple throughout. The natives of the table-land districts plant many varieties together, but know the names and qualities of the different kinds as we do the numerous kinds of apples.

bolism, with the complicated hieroglyphic figures of the ancient Mayas of Central America. Notable artistic ability was also manifested in pottery, poetry and music.

Astronomical Determination of Seasons

The natural conditions of the development of agriculture in Peru also tended strongly to encourage observation of the seasonal changes in the position of the sun. The ancient remains show that crowded populations lived in narrow valleys and canyons where the chance of growing crops on the steep slopes was acutely dependent on exposure to the sun. This was especially important at the higher altitudes where the seasons are short and precarious. Each center of population appears to have had its *intihuatana* or sunpost, for direct observation on the shadow of the sun to determine the advance of the season. Stone pillars were set up to mark the elongation of the shadow, the name *intihuatana* meaning literally the sun's hitching post. The power to hold the sun, to bring it back from the solstice and to control the weather, was ascribed to the Inca, and was the basis of his sacred authority, much as in China where the emperor was considered responsible for good and bad seasons.

Social Organization and Colonization

The ancient inhabitants of Peru extended the practice of agriculture and the attendant arts over a very

wide area by means of a superior system of social organization, quite unparalleled in other parts of America, which made it possible to plan and construct extensive systems of terracing and irrigation, and to send out regularly recruited, well-organized colonies to populate new districts. Thus the Inca Empire at the time of the discovery and conquest was by far the most extensive and populous of the native American states.

Public storehouses were a feature of the Inca polity, that made a very favorable impression upon the early Spanish historians, but were not maintained after the conquest. The storehouses served to increase production by making it possible to cultivate the higher valleys where in some years the crops were destroyed by untimely frosts. But with the storehouses to protect the people from famine, sufficient food could be grown in the favorable seasons. Corn enough for five years is said to have been stored in some districts. Thus in the old days people lived in many of the higher valleys that are now entirely deserted.

The storehouses were substantial structures, with walls of masonry, many of which are still standing and might be used if the roofs were replaced. Many of the buildings that have been described as fortifications or nunneries, because of their inaccessible locations, are more likely to have been storehouses, as the long high building shown in Figure 9, perched on the crag above the landslide, overlooking the valley of Ollantaytambo. The cool, dry places probably were chosen to keep the stored products in better condition. The storehouses shown in Figure 17 were in a high pass between two important valleys.

Far beyond the range of political power of the Incas, language and other traces of Inca influence have been found in many parts of eastern and northern South America, and possibly extending through the West Indies to Central America and Mexico. The general similarity and wide distribution of the native languages of the Brazilian and even the West Indian region are further evidences of extensive movement of agricultural populations, sometimes, no doubt, replacing and sometimes fusing with more primitive inhabitants.

The natural movements of progress are from centers of population and civilization to less occupied regions. Natural products are carried in and the products and arts of civilization are carried out, sometimes for great distances. For centuries yet uncounted the Peruvian region was the chief center of intensive agriculture and crowded population, and it is reasonable to seek in that quarter the origins of the plants that were widely distributed and formed the general basis of agriculture in other parts of America.

Summary

Domestication should be studied as a biological problem, laying aside the traditional assumption of a primitive pastoral state. Plants probably were domesticated before animals, and this is definitely indicated in America. The primitive civilizations of America were an indigenous development, since they were based on native American plants. A general unity of the native agriculture of America may be recognized, in view of the wide dissemination of the maize plant, usually accompanied by beans, squashes and several attendant species.

The Peruvian region was the chief center of domestication in America, as shown by the large number of plants that were cultivated, estimated at seventy species, and several species of animals.

A study of the native names of cultivated plants in Peru indicates that all of the principal lowland crop plants of other regions were known to the ancient Peruvians before the Spanish conquest. Wild prototypes of these plants have not been discovered in other parts of America and may be sought in the Peruvian region.